GRASSLAND BASIN IRRIGATION AND DRAINAGE STUDY

VOLUME 1 - FINAL REPORT

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IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407

Phone: (805) 756-2434 FAX: (805) 756-2433

PROJECT CONTRIBUTORS

This project was managed by the Irrigation Training and Research Center at Cal Poly, San Luis Obispo. The contract was with the California Regional Water Quality Control Board (RWQCB) to perform the Grassland Basin Irrigation and Drainage Study. Contacts at the RWQCB were:

- **Dennis Westcot** - California RWQCB - Central Valley Region
- **Ross Steensen** - California RWQCB - Central Valley Region

PROJECT MANAGEMENT

- **Stuart Styles** - Project Manager. California Polytechnic State University (Cal Poly) - Irrigation Training and Research Center at San Luis Obispo. Responsible for report preparation and coordination with subcontractors.

- **Dr. Charles M. Burt** - Principal Investigator. Cal Poly - Irrigation Training and Research Center. Responsible for project formulation and technical review.

SUB-CONSULTANTS

- **Dr. James Ayars** - USDA/ARS, Water Management Laboratory, Fresno, California. Dr. Ayars provided input for the pre-plant irrigation efficiency analysis and support for the private well analysis.

- **Joe Karkoski** - Regional Water Quality Control Board. Mr. Karkoski provided an analysis of the drainage flows and water quality.

- **Dr. Dennis Wichelns** - Dr. Wichelns provided an analysis of the on-farm practices being adopted within each of the districts that are having an impact on the irrigation efficiency values for the study area.

- **John Fio** - US Geological Survey, Sacramento. Mr. Fio provided an analysis of the subsurface water components of the water balance.

DISTRICT PERSONNEL

This project was completed with the assistance and close cooperation of the water and drainage districts in the Grassland Area. Information on the amounts of delivered water, tailwater, tile water, and irrigated acreage (as well as other data) for the last 12 years was provided. Particular thanks are extended to:

- **Steve Chedester** - Firebaugh Canal Water District
- **Dennis Falaschi, Don Anderson, and Marcos Hedrick** - Panoche Water District
- **David Dermer** - Pacheco Water District
- **David Cone** - Broadview Water District
- **Mike Porter, Bob Pfitzer, and Chris White** - Central California Irrigation District
- **Doyle Perry** - Charleston Drainage District

All of these individuals took time from their very busy schedules to respond to repeated requests for information. In addition, this report required input from several other entities.

ITRC PERSONNEL

- **Dr. Walt Bremer** - Cal Poly, Landscape Architecture Department. Dr. Bremer helped to generate the GIS database used for this project.
- **Christina Roberts** - Cal Poly, Irrigation Training and Research Center. Ms. Roberts worked on the data collection for the annual irrigation efficiency analysis. Site visits to each of the districts were made and water delivery/acreage data verified.
- **Charles Tilt** - Cal Poly, Irrigation Training and Research Center. Mr. Tilt performed the pre-plant irrigation efficiency analysis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

United States Department of Agriculture/ Agricultural Research Service	ARS
Available Water Holding Capacity	AWHC
Broadview Water District	BWD
Columbia Canal Company	CCC
Central California Irrigation District	CCID
Charleston Drainage District	CDD
Cubic Feet per Second	CFS
California Regional Water Quality Control Board	CRWQCB
Central Valley Regional Water Quality Control Board	CVRWQCB
District Irrigation Efficiency	DIE
Delta-Mendota Canal	DMC
Drainage Opperation Plant	DOP
Distribution Uniformity	DU
California Department of Water Resources	DWR
Electrical Conductivity	EC
Electrical Conductivity of a Soil Paste Extract	ECe
Drainage Water Electrical Conductivity	ECdw
Environmental Impact Report	EIR
Enivironmental Impact Survey	EIS
Crop Evapotranspiration	ETc
Firebaugh Canal Water District	FCWD
Firebaugh Drainage Association	FDA
Geographic Information System	GIS
Grassland Water District	GWD
Irrigation Efficiency	IE
Panoche Drainage District	PDD
Panoche Water District	PeWD
Pacheco Water District	PoWD
Soil Conservation Service	SCS
San Luis Canal Company	SLCC
San Luis Water District	SLWD
Soil Moisture Depletion	SMD
State Water Resources Control Board	SWRCB
Total Dissolved Solids	TDS
United States Bureau of Reclamation	USBR
United States Fish and Wildlife Service	USFWS
United States Geological Survey	USGS
United States Salinity Laboratory	USSL
United States Weather Bureau	USWB
Water Conservation Plan	WCP
Water Conservation Report	WCR
Water Drainage Report	WDR
Westlands Water District	WWD

EXECUTIVE SUMMARY

This project analyzed the district irrigation efficiency for 6 subareas of the Grassland Basin roughly representing 80,000 acres on the west side of the San Joaquin Valley near Firebaugh, California. The subareas are identified in this report as Broadview Water District (BWD), Central California Irrigation District (CCID-Camp 13), Charleston Drainage District (CDD), Firebaugh Canal Water District (FCWD), Pacheco Water District, (PoWD), and Panoche Drainage District (PDD). The time span for this study was the period from 1981 through 1992.

The objectives of this project were as follows:

- Determine the district irrigation efficiency for the 6 subareas.
- Update district drainage policies and water reuse.
- Update the geographical information system (GIS).
- Perform a pre-plant irrigation efficiency analysis.
- Establish a relationship between the drainage volumes and the district irrigation efficiency.
- Determine the maximum district irrigation efficiency attainable.
- Determine the impact of optimizing district irrigation efficiency on loads and concentrations leaving the districts.
- Determine actual farm practices, salt build-up, cropping, etc. that have been impacted by drainage and surface runoff water reuse.

The following is a summary of the tasks completed in this report.

Section 1 Summary: Re-Use Of Surface Runoff And Subsurface Drain Water

The significant increase in the re-use of surface runoff and subsurface drain water, at both the farm-level and district-level in the Grassland Drainage Basin, have provided farmers and districts with much-needed augmentations of contractual water supplies and have resulted in significant reductions in the volume of drainage water discharged from districts to the San Joaquin River and its tributary sloughs. The desire to achieve regional water quality objectives will also remain in place, although farmers and districts realize that reductions in drain water volume may not increase the probability that the Mud Slough (North) and Salt Slough water quality objectives can be met.

The previous six years have provided farmers, district managers, and regional water quality authorities with an opportunity to observe the short-term challenges for re-using subsurface drain water. Many farmers have also begun to observe or to report on the potential long-term impacts of re-using subsurface drain water in the Grassland Drainage Basin. Several themes describing the opportunities and challenges to re-using drainage water have emerged during interviews with farmers and district managers in the region.

- One of the principal concerns expressed by all of the managers interviewed in this study is the difficulty and expense involved in distributing recycled drainage water throughout a large portion of an irrigation district. Several of the managers reported that their current water delivery and return systems do not permit them to deliver recycled drainage water to all of the lands that may have generated the drainage water.

- The equity and efficiency issues regarding drainage water re-use are short-term issues that district managers have attempted to address through careful adjustment of water volumes and concentrations in response to specific requests from farmers receiving recycled drainage water. In the long-term, district managers suggest that expensive construction projects may be required to build new recirculation facilities for moving drainage water to all portions of an irrigation district.

- Some of the managers also reported a concern regarding the linkage between water quality objectives in the San Joaquin River, Mud Slough (North), and Salt Slough, and the volumes and concentrations of drainage water released at district discharge outlets. In particular, the managers perceive a lack of information regarding the specific strategies that districts should pursue in managing subsurface drain water. Strategies designed to reduce drain water volumes and loads will likely result in higher concentrations of boron and selenium at district discharge outlets. Thus, while the probability of achieving water quality objectives in the San Joaquin River will be increased, the concentrations of boron and selenium in Mud Slough (North) and Salt Slough will also be increased.

- Several farmers operating in the Grassland Drainage Basin were also interviewed in this study, to receive input regarding the short-term and long-term implications of re-using subsurface drain water. One of the farmers has been re-using drainage water for more than six years to augment limited water supplies. That farmer reports no yield effects on cotton and sugar beets, to date, but he does report noticeable damage on a field of alfalfa hay. This is the first year he has noticed the damage, but he feels this is the beginning of permanent difficulty with his recycling program, unless he is able to leach salts from the soil in the near future. In recent years, he has had to increase the volume of water delivered to his fields, as the quality of water has declined. Continued application of high-salt water to his fields has resulted in saline soils that restrict the ability of plants to extract water.

- The large expense required to construct ideal facilities for maximizing the potential re-use of drain water will not be allocated by districts, given current economic conditions and uncertainty regarding water supply and drainage issues. Districts and farmers will likely continue to pursue short-term solutions to district-wide drainage management issues until a clearer plan is presented to them regarding their individual or district roles in achieving regional water quality objectives.

Section 2 Summary: Drainage

Recycling

The districts in the study area have different options available for handling surface runoff and subsurface drainage. The drainage strategy is made up of five different policy levels: Acceptance, Separation, District Level Recycling, Holding, and Assimilation Water. Each of these levels was analyzed for each district. **Table ES-1** is a listing of these drainage policies and a brief description of the policy.

Table ES-1
District-Level Drainage Policies

Policy	Description
Acceptance	Decision by districts to accept or deny drainage or surface water into district surface drains.
Separation	If a district accepts both tile water and tailwater, the next policy decision is whether or not to keep them separate.
Recycling	The next policy decision is whether or not a district will recycle any of the water back into the supply.
Holding	Storage of drainage water could be required to meet water quality standards.
Assimilation	Blending of the drain water with better quality water to meet water quality standards.

- Acceptance Of Tailwater and Tilewater. All districts are currently accepting both tile water and tailwater. However, PDD's formal policy is to not accept tailwater and that policy will soon be completely enforced. BWD has plans for installing a new turnout on the San Luis Canal. If this installation is completed, BWD will no longer accept tailwater either. Although this report does not include detailed information about on-farm recycling, there is already considerable on-farm recycling of tailwater in the study region especially within PDD and PoWD.

- Separation Of Tailwater And Tilewater. CDD's drainage system keeps tile water separate from tailwater on the upslope side of the DMC. Once pumped across the DMC, tile water and tailwater are commingled in the open drains. PoWD is attempting to keep tile water and tailwater separated. All other districts commingle tile water and tailwater.

- District Level Recycling. CDD does not recycle any drainage water at the district level. CCID, while recycling substantial amounts of drainage water in other parts of their system, is recycling only one tile sump of ten in the 6,000 acre Camp 13 Study Area. PeWD has only recycled drainage water in the past two years. PoWD, and BWD recycle substantial amounts of drainage water. FCWD recycles a significant portion of their drainage water.

- Holding Facilities. Only Panoche Water District (PeWD) has an external holding facility, and this is only a pilot project.

- Assimilation. CCID has indicated that it can blend its problem drainage water with its own irrigation water. FCWD and BWD have not indicated what their formal policies will be in the future. CDD, PDD, and PoWD have indicated that they will maximize their use of the San Joaquin River's assimilative capacity. Formal policies are lacking at all districts that would govern the extent of recycling, the allowable water quality limits for blended irrigation water, and division of the assimilative capacity of the San Joaquin River among the area drainers.

Obviously the on-going drought has had an impact on the amount of recycling and drainage. It is impossible to accurately predict district operations in a normal year. Looking at pre-drought years would probably not be appropriate due to the change in the political/regulatory climate regarding agricultural drainage in the area.

Geographical Information System (GIS)

The GIS database was updated and utilized several times throughout the course of this project. The database has been transmitted to the USBR (through Internet), USSL in Riverside (tape file), and to the USGS in Sacramento (tape file). Copies of the file can be made for other entities wishing to perform analysis of the study area using GIS. **Appendix A** includes a detailed description of the GIS developed for this project.

An ARC/INFO database has been developed for this project to manage all of the map data. Although initial maps were down-loaded from the Bureau of Reclamation's computer in Sacramento at the start of the project, many changes to the existing data were found to be necessary. Therefore, data was re-digitized from existing map sources and field checking using a USGS 7.5 minute quad series as the base. The quads are as follows:

Charleston School	Mendota Dam	Laguna Seca
Dos Palos	Firebaugh	
Oxalis	Broadview Farms	
Poso Farm	Hammonds Ranch	

These maps were supplemented with field information and other map bases received from various agencies. The GIS database presently contains basic information. The location data has been used extensively to generate maps and determine the physical interrelationships between districts. Parameters have been assigned to each of the input points and segments (such as the length and direction of flow). However, detailed information has not been incorporated into the database. For example, the monthly solute loadings for each sump for the 12 year study period are available in computer spreadsheet files. These files contain a tremendous amount of data that has not been filtered nor added to the ARCINFO database. As other entities utilize the database to expand the analysis of the study area, that data will be retrieved and used to update (and expand) the master files maintained at Cal Poly.

Subsurface Flows

John Fio, with the USGS in Sacramento, used the GIS to perform an analysis of the base flow for the study area. The sump discharge data for all of the sumps in the study area was analyzed for the study period. Low flows have been assumed to approximate the most accurate determination of the base flow. The base flow was defined for this study as the net groundwater inflow to the region from outside of the study area boundaries measured in the surface discharge measurements during the nonirrigated periods.

Sump discharge data from Broadview, CCID-Camp 13, Charleston, Firebaugh, Pacheco, and Panoche districts was obatined and formatted to a single spreadsheet application. High flows

(January through September - in general) were separated from low flows during the non-irrigated time of the year (October-December).

The data collection effort uncovered an important recommendation for future activities for the districts. All data should be reported in a consistent format with well-defined protocols for data storage and retrieval. For example, all data could be provided in ASCII format. Retrieval of the raw data was a significant amount of the expense for this portion of the study due to differences in reporting formats, embedded graphs, and programmed cell formulas.

The estimated drainflow for this study in 1992 (most complete data set) was as follows; Broadview-52 AF, CCID C13-No Estimate, Charleston-30 AF, Firebaugh-409 AF, Pacheco-575 AF, Panoche-970 AF. The total low flow volume was 2,036 AF for the entire study area. The total sump flow was estimated at 15,165 AF. The low flow represents about 13% of the total sump flow for the study area. The low flow total would respresent a minimum base flow since it does not account for baseflow during the irrigation months.

An estimate of incidental recharge below the Corcoran clay was also required for the water balance in this study. Preliminary results from a steady-state groundwater-flow model construicted by Fio (in review) indicate the following simulated incidental recharge to the aquifer below the Corcoran Clay; Panoche-0.54 AF/yr, Broadview-0.31 AF/yr, Firebaugh-.26 AF/yr.

Well pumping estimates were made by contacting individual growers in the study area. It was not possible to obtain values that were reasonable. Estimates of groundwater pumping were made by evaluating the ETc requirements. This was significant for Panoche Drainage District in 1991 and 1992 where groundwater pumping represented about 30% of the water supply.

Section 3 Summary: District Irrigation Efficiency - Crop ET (ETc) Approach

The DIE includes water lost from operational discharges and seepage losses from supply canals. The irrigation efficiency is calculated with the following equation:

$$\text{DIE} = \frac{(\text{ETc with adjustment} + \text{Leaching required for salt control} - \text{Effective Rain})}{\text{Irrigation Water Applied}} \times 100$$

Where; DIE = District Irrigation Efficiency (%)

ETc = Adj. ETc values (reduction for poor stands and bare spots)

Leaching = Water applied for leaching of salts

Effective Rain = Rain used by crops or for salt control

Table ES-2 summarizes the calculated values. The low irrigation efficiency values in 1983 and 1986 occured during years that were high rainfall amount years. Broadview Water District had high values in 1981 and 1982 which then decreased in 1983 when BWD obtained an outlet to the San Joaquin River. The 80% efficiency represented a very high efficiency with 100% recycling of tailwater and tilewater. Since the water quality degraded to a unsatisfactory value, the ***80% may well represent the range of maximum sustainable irrigation efficiency.*** Note that after several years of high irrigation efficiency, the DIE drops in value significantly in Broadview. This can be partially explained by the result of leaching done in subsequent years to make up for short water years. This means that the highest values on the table may reflect levels that are not maintainable.

Figure ES-1 shows the irrigation efficiency using the ETc approach graphically. The trend is definitely one of increasing irrigation efficiency over the 12 years of the study. This reflects a necessary reaction by growers and districts to respond to decreasing water supplies and increasing environmental, political, and social concerns of drainage.

Table ES-2
District Irrigation Efficiency
ETc Approach

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Broadview	81%	81%	58%	57%	55%	51%	56%	58%	62%	73%	87%	94%
CCID	48%	48%	44%	51%	61%	63%	71%	73%	87%	77%	66%	71%
Charleston	59%	62%	62%	43%	42%	47%	45%	55%	68%	68%	71%	73%
Firebaugh	55%	55%	61%	53%	51%	52%	53%	61%	68%	75%	77%	70%
Pacheco	67%	84%	72%	77%	68%	67%	75%	70%	60%	68%	76%	86%
Panoche	58%	40%	62%	54%	61%	57%	61%	66%	72%	75%	78%	80%

Section 4 Summary: Pre-Plant Irrigation Efficiency

Examination of pre-plant irrigation efficiencies for five of the Grassland Basin districts was completed in order to determine the potential for reduction of drainage water from the area during the period of time when pre-plant irrigation events occur (December through March). In theory, the time frame for the poorest irrigation efficiencies occurs during the pre-plant irrigations since irrigations are required for germination, but the soil moisture deficit may not warrant the quantity of water applied.

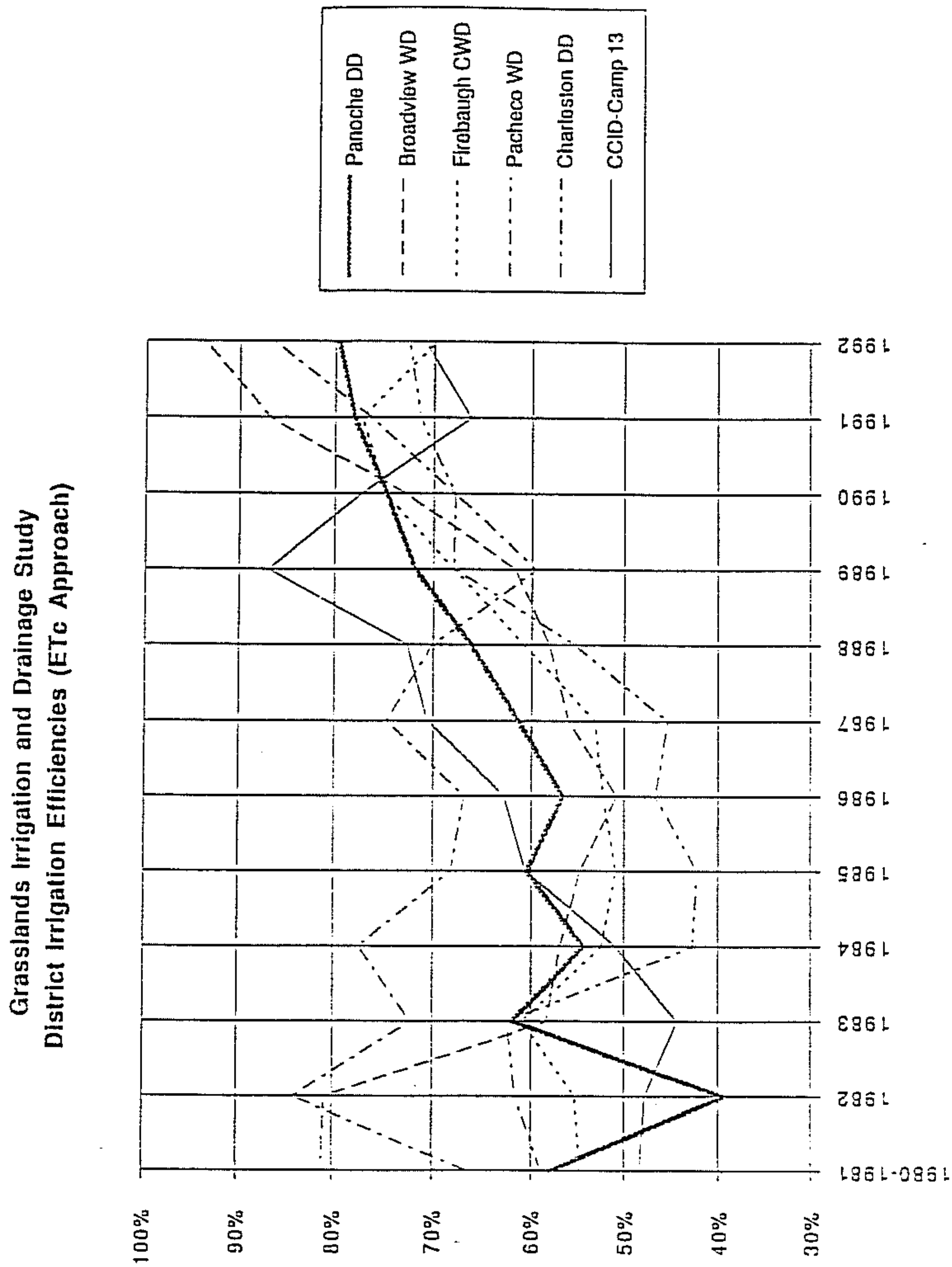

Grasslands Irrigation and Drainage Study
District Irrigation Efficiencies (ETc Approach)
Panoche DD
Broadview WD
Firebaugh CWD
Pacheco WD
Charleston DD
CCID-Camp 13
100%
90%
80%
70%
60%
50%
40%
30%
1980-1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

Figure ES-1

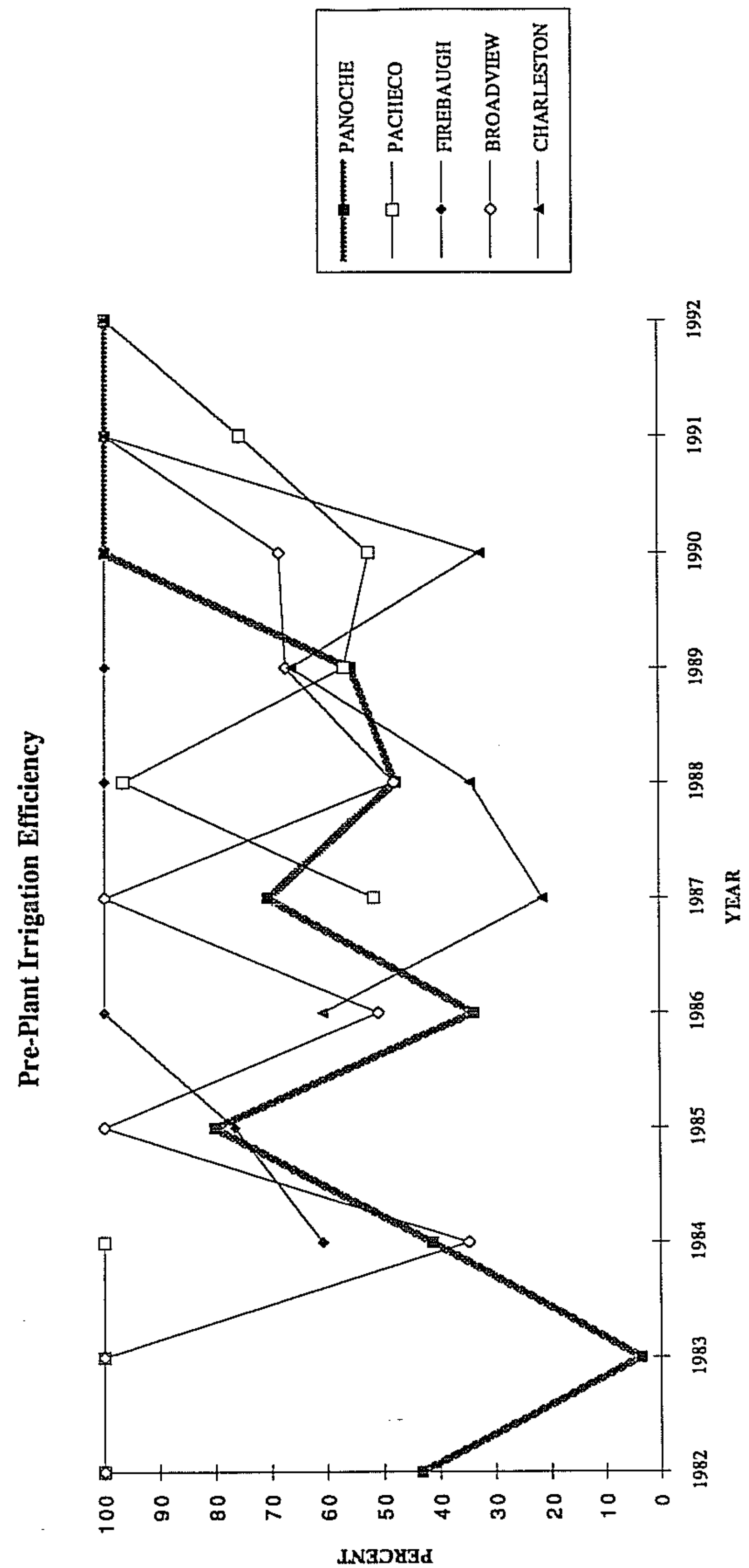
The study of the pre-plant irrigation efficiencies depends on the application of broad-based and theoretical assumptions about agricultural practices to highly variable and site specific cropping and irrigation patterns. Furthermore, the information available from the water districts involved is general in nature. Given these limitations, quantifying the data and arriving at specific numbers for district-wide pre-plant irrigation efficiencies for a certain portion of the cropping season is a task which requires a certain amount of professional skill to evaluate the results.

The intention in this portion of the study was to obtain numbers which would reflect trends in pre-plant irrigation efficiencies and indicate the degree of need for modifying irrigation practices during the time of year when pre-plant irrigation occurs. **Figure ES-2** shows the irrigation efficiency using the Pre-Plant Irrigation Efficiency approach graphically. Results indicated overirrigation (low irrigation efficiencies) prior to 1990. Results also indicated poor irrigation efficiencies during high rainfall years. Rainfall in the pre-plant months tended to decrease the irrigation efficiency in this analysis. However, the rainfall may not have been beneficial to the individual farmer depending on several factors. Results for 1990 through 1992 generally indicated underirrigation during the pre-plant months (high irrigation efficiencies). The following main conclusions were drawn from the data:.

- The data indicate that growers are adjusting water deliveries in response to the quantity of effective rainfall.
- Low PIE values can generally be explained where growers are applying excess water in one year to satisfy leaching requirements from previous years.
- High PIE values from 1990-1992 in some of the districts reflect inadequate water supplied for leaching.
- 1993 can be expected to be a low PIE year if water was available.

Section 5 Summary: Regional Irrigation Efficiency - Water Balance Approach

This section of the study was designed to be a check against the DIE which was computed with the ETc approach. The Water Balance approach used the reported district drainage (and its quality) to determine the DIE. If a district acts hydrologically as a "bathtub" , this is a reasonable approach. Because there are difficulties in determining drainage outflows from individual didtricts, the data was eventually grouped to estimate a regional IE.



Pre-Plant Irrigation Efficiency
PANOCHE
PACHECO
FIREBAUGH
BROADVIEW
CHARLESTON
PERCENT
100
90
80
70
60
50
40
30
20
10
0
YEAR
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

Figure ES-2

Since 1985, additional data has been collected and reported for the drainage volumes discharged by the districts. Using this data and some assumptions regarding subsurface water flows, an estimate of the irrigation efficiency using a "bathtub" or water balance approach was completed in order to verify the validity of the values generated by the theoretical ETc approach.

The Regional Irrigation Efficiency values were determined for water years 1986 to 1992 depending on what information was available. In this report, 1986 refers to the water year October 1, 1985 through September 30, 1986. The goal was to verify the relative values of the DIE estimates using the ETc approach. Note on this table that Broadview Water District, CCID-Camp 13, and Firebaugh Canal Water District are referred to as the Eastside Districts. This was done since they all drain through one, common drainage point (FC-5).

Table ES-3 shows the calculation of the district irrigation efficiency based using a water balance approach and using the following equation:

$$IE = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied}} \times 100$$

Also shown on this table is the comparison to the Regional IE estimate from the ETc approach. The data for the regional irrigation efficiency for both approaches is shown in **Figure ES-3**. The values trend similar to each other indicating increasing irrigation efficiencies as the drought continued into the 6th year (1992). The values are 5% or less difference starting in 1987. The values are within 3% in the years 1989 through 1992. This close comparison of results of two entirely different calculation procedures validates the assumptions used in the ETc Irrigation Efficiency approach.

Table ES-3
Irrigation Efficiency - Water Balance Approach

	1986	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Panoche (DIE)	64%	61%	64%	69%	69%	72%	69%
Pacheco (DIE)	48%	45%	73%	66%	72%	79%	68%
Charleston (DIE)	59%	59%	52%	69%	72%	82%	83%
Eastside Districts (BWD, FCWD, CCID-Camp 13)	66%	68%	74%	75%	78%	77%	77%
Regional IE (Water Balance Approach-Weighted)	**64%**	**64%**	**69%**	**72%**	**73%**	**76%**	**74%**
Regional IE (ETc Approach)	**56%**	**59%**	**64%**	**70%**	**75%**	**78%**	**77%**

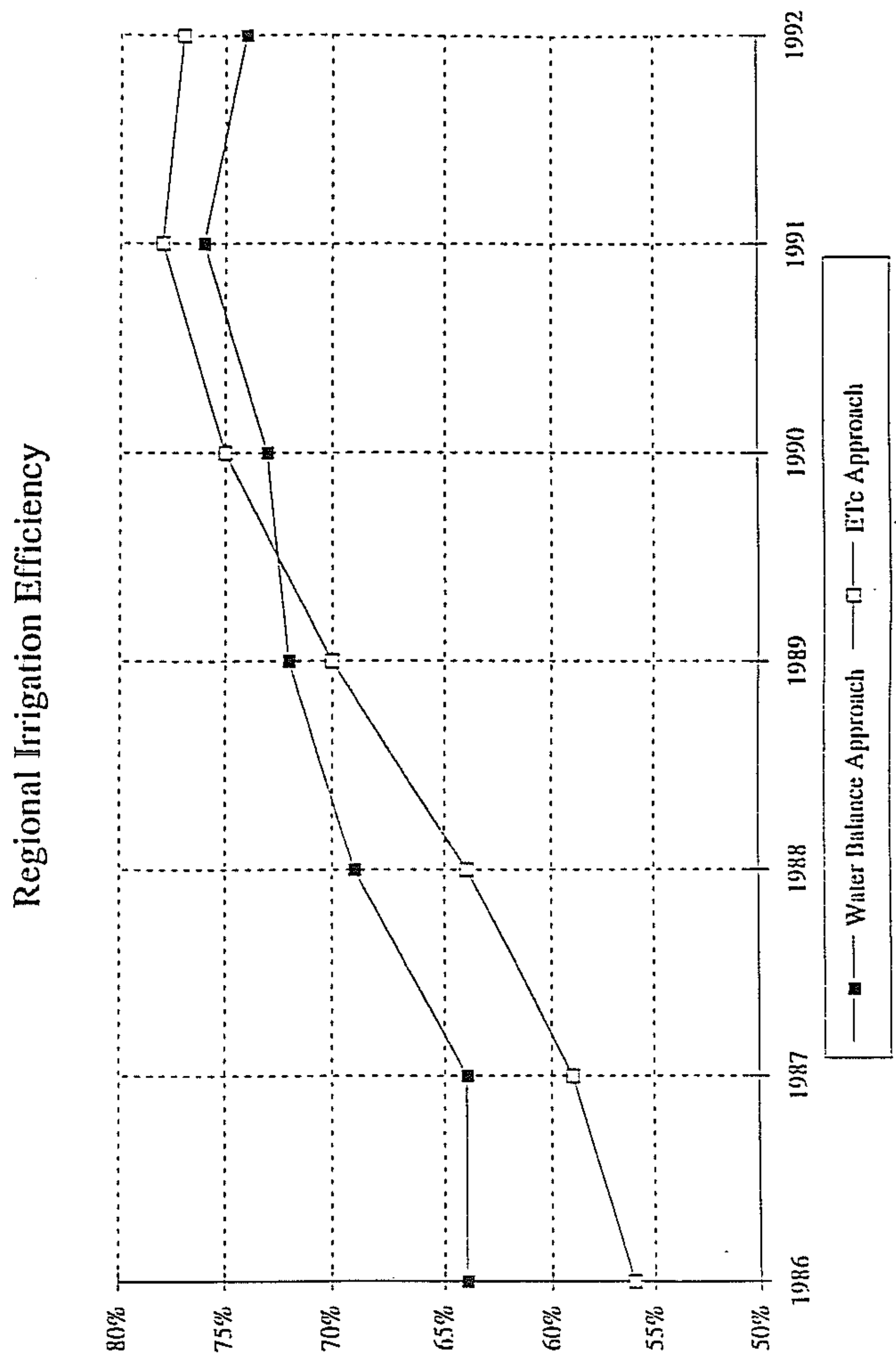

Regional Irrigation Efficiency
80%
75%
70%
65%
60%
55%
50%
1986
1987
1988
1989
1990
1991
1992
Water Balance Approach
ETc Approach

Figure ES-3

Section 6 Summary: Conclusions

One effect of the drought may well be a reduction in the ETc adjustment factor as farmers stress crops. Another factor might be farmers planting more acreage than prudent; hoping for extra water to appear in mid-season. Without the additional water, some acreage will be abandoned. These abandoned acreages would have to be considered separately if performing further analyses in the same manner as this study.

The results of this study indicate that most of the districts were able to improve DIE. The main problem is whether they can maintain the high levels of irrigation efficiency without being impacted by increasing salinity in the rootzones. Based on the pre-plant analysis, the data indicated that significant underirrigation was being practiced due to the limited irrigation water supplies. If the trend were to continue, excessive levels of salts in the rootzone would be expected.

The results also indicate a basic need for better coordination among the districts in the data collection and recording efforts. The districts might invest in a common spreadsheet and word processing format to aid in information transfer. There has been much data collected for this study area. However, most of the data is not readily accessible for data analysis. Some of the data monitoring sites need to be improved. For example, wells and drainage sumps must be fitted with flowmeters. Other suggestions include standardized procedures for the collection of water quality data, improved drainage discharge point measuring stations, and standardized format for reporting irrigated acreage and water delivery data (suggest the September through October format).

An important assumption made in this study was adjusting the ETc downwards to account for nonuniformity and bare spots (about 15%). This tended to decrease DIE using the ETc approach because it decreases beneficial use for the same amount of applied irrigation water. This assumption appeared to be verified by comparing the ETc approach results of DIE with the water balance approach.

<u>Other Significant Results</u>:

- The water balance approach has identified several destinations of water that have not been used in previous reports. These include an estimate of the amount of rainfall runoff that enters the drains. The total amount ranged from about **4,500 AF to 10,000 AF** for the entire study area based on 50% of the total rainfall between October and March. Another estimated value was the amount of deep percolation losses below the Corcoran Clay layer. This report estimated losses of about **23,100 AF** per year for the study area. This is compared to the measured drainage volume in 1992 of **30,500 AF**. This is significant because a salt balance of this region needs to include an estimate of the salt removed with the water passing through the Corcoran Clay.

- Due to the fluctuating characteristics of the water quality data from the sumps and the district drains, it was felt it was not possible to draw conclusions regarding the expected selenium, salinity, or boron levels with additional recycling. Future data collection efforts need to focus on consistant water quality measurements and accurate flow measurement devices. Reported water quality measurements appear to use averaging techniques that may not accurately reflect the water quality in the drains. Some of the drainage discharge measurement sites need improvements to ensure accurate water measurement. Concentrations and loads analysis was graphically performed in **Appendix G**. Included in this section are EC, Se, B versus time of year, EC versus Drainage Volume, and EC versus Se ratios.

- In addition, special analyses were made of the sumps in Panoche Drainage District. It was found that 50% of the reported load of Se into the discharge of the district comes from 5 of 61 sumps. 80% of the loading comes from 10 of the sumps. These sumps are located close to each other on the eastern side of the district. If flows from these sumps could be minimized, the impact on the drain Se loading would be significant. Future studies may want to focus on water table control in these areas to minimize drainage volumes. For example, maintaining higher water tables could force additional upflux from the shallow water table. It is recognized that these regions may be draining significant flows from upslope water users. PDD has also been at the forefront in researching methods to remove harmful salts from the drainage water.

- It was found that the water quality from individual sumps varies significantly and that this is due to variations in the timing of the water quality samples. Apparently, water samples are drawn when convenient and costs do not allow consideration for the timing of irrigation events. However, the data indicates that reductions in the drainage volumes will definitely reduce the EC, Se, and B loadings in the drains with the tradeoff of some increase in the concentrations.

Future of the Grassland Basin

Long-term success for farmers in the Grassland Drainage Basin might be defined as "maintaining acceptable agricultural profitability while meeting the water quality standards in the San Joaquin River". This success will depend on the drainers' ability, in the Grassland Area, to control the timing and amount of salt movement to the San Joaquin River. This ability will be affected by:

- Modifications to on-farm tile drain systems and irrigation practices that could possibly reduce the pickup of salts, especially selenium (ie., closer tile line spacings, maintenance of higher water table, and water table control for maximum crop use).
- Individual district strategies for disposal of drainage water (increase DIE).
- Cooperation among the districts in jointly meeting water quality standards.

Unblended agricultural drainage that leaves a district's boundaries will almost always be of worse quality than the water quality standards of the San Joaquin River. Thus, drainage water must be blended with better-quality water. There are two possible sources for blending water:

1. The natural flows of the San Joaquin River
2. High quality drainage water which leaves a district

Future actions by various regulatory agencies may restrict the amount of San Joaquin River water which can be used by districts to blend with their drainage water. If this occurs, districts will have to use their own irrigation water supply. In either case, districts can develop a management strategy if they have internal control of drainage amounts, qualities, and destinations.

Increasing the DIE will result in reduced drain water volumes and lower loads. Reduced drain water volumes and loads will result in higher concentrations of boron and selenium at district discharge outlets. Thus, while the probability of achieving water quality objectives in the San Joaquin River will be increased, the concentrations of boron and selenium in Mud Slough (North) and Salt Slough will also be increased.

There are two reasonable approaches available towards increasing the DIE in this area.

- The first is the classical approach of improved water management on both district and on-farm levels.

- The second path is a relatively new idea. This approach is an integrated approach which attempts to maximize the ratio of crop yield to the unit-water applied. Through improved management of the soil fertility, planting, irrigation, and other agronomic factors, the zones in a field which have weak or bare crop growth will be eliminated or minimized. Therefore, with a stronger crop, the field ET will increase because there are more and healthier plants. The applied water would remain about the same. The net result is less deep percolation and a higher IE.

Sustainable District Irrigation Efficiencies

There are two important and related questions which the ITRC has addressed in this study:

- What is the highest District Irrigation Efficiency (DIE) which can be sustained in this
- How much tile water recycling can be done?

The evidence to date indicates that the answers are three-fold:

- If there is under-irrigation on fields (caused by a combination of short durations and non-uniformity), any tile water recycling appears to be unsustainable in that some portions of the fields will accumulate unacceptably high and toxic salt levels.
- If there is no under-irrigation on fields (ie, all non-uniformity is compensated for with extra water application, and irrigation scheduling is sufficient to have no stress anywhere), about 30% of the deep percolation through the root zone can be recycled without raising the average root zone ECe to more than about 2.5 dS/m. The remaining 70% of the root zone deep percolation will either exit through the Corcoran Clay layer or be discharged (via tiles and then surface drains) from the district. Because of the uncertainties of the magnitude of the flow rate downward through the Corcoran Clay layer, it is impossible to predict the precise amount of tile water that must be discharged from the district via surface drains.
- The maximum sustainable DIE is about 80% in this region.

These conclusions are based upon the following:

1. All on-farm irrigation has non-uniformity (Distribution Uniformity, DU, of less than 100%) of water distribution across a field. Typical well-managed and well-designed irrigation systems have a DU of about 75-80%.

2. To avoid under-irrigation, with a DU of 75% and about 5% non-beneficial evaporation loss, the Irrigation Efficiency (IE) of a farm with no recycling is about 70%

$$IE = DU \times \left(1 - \frac{\%\ \text{evap loss}}{100}\right)$$

$$= 75 \times \left(1 - \frac{5}{100}\right)$$

$$= 71\%$$

3. A simple spread sheet was developed to examine soil salinities across a field with a linear DU pattern and varying percentages of tile recycling. A 30% recycling of root zone deep percolation, accomplished through blending tile water with supply water, indicated that the drainwater EC and blended water EC stabilize within a couple of years. This assumes **<u>no under-irrigation</u>** (a key assumption, as explained below). Estimated stabilized values were:

   EC of source water = 0.6 dS/m (assumed)
   ECe at "worst spot" in the field = 2.6 dS/m
   ECe at "best spot" in the field = 0.5 dS/m

   ECiw (blended) = 0.8 dS/m

   ECdw = 2.5 dS/m

4. The numbers in item (3) above do not match what is actually seen in field. In particular, Broadview Water District has excellent data since about 1980. That data shows the following:

- Before BWD had an outlet for its tile drain water, the EC of the blended irrigation water was about 3.0 dS/m, higher than predicted in (3).

- This report has estimated that the present annual DIE values and pre-irrigation DIE values are in the range of 90%.

- Soil salinities measured throughout BWD by Lesch and Rhoades in 1991 are much higher than the ECe's predicted.

- The high DIE values in BWD are indicative of under-irrigation on parts of fields. That under-irrigation leads to salt build-up (due to no leaching) in some parts of fields, and very concentrated tile drain water in the areas with some leaching. That concentrated tile drain water is then recirculated on all the field, compounding the problem.

5. The district farmers see processing tomatoes as a key crop in their economic rotation. Tomatoes have a threshold (critical maximum) ECe of about 2.5 dS/m for soil salinity. Therefore, this discussion of sustainability revolves around the objective of maintaining a soil salinity distribution such that there is no yield decline of tomatoes anywhere in the field due to salt buildup.

In summary, the evidence indicates that the best strategy for soil productivity sustainability requires all three of the following:

- Have high irrigation DU's.

- Have excellent irrigation scheduling and water depth control, and avoid under-irrigation

- Recycle no more than about 30% of the root zone deep percolation, which may be equivalent to 40-60% of the tile water.

SECTION 1

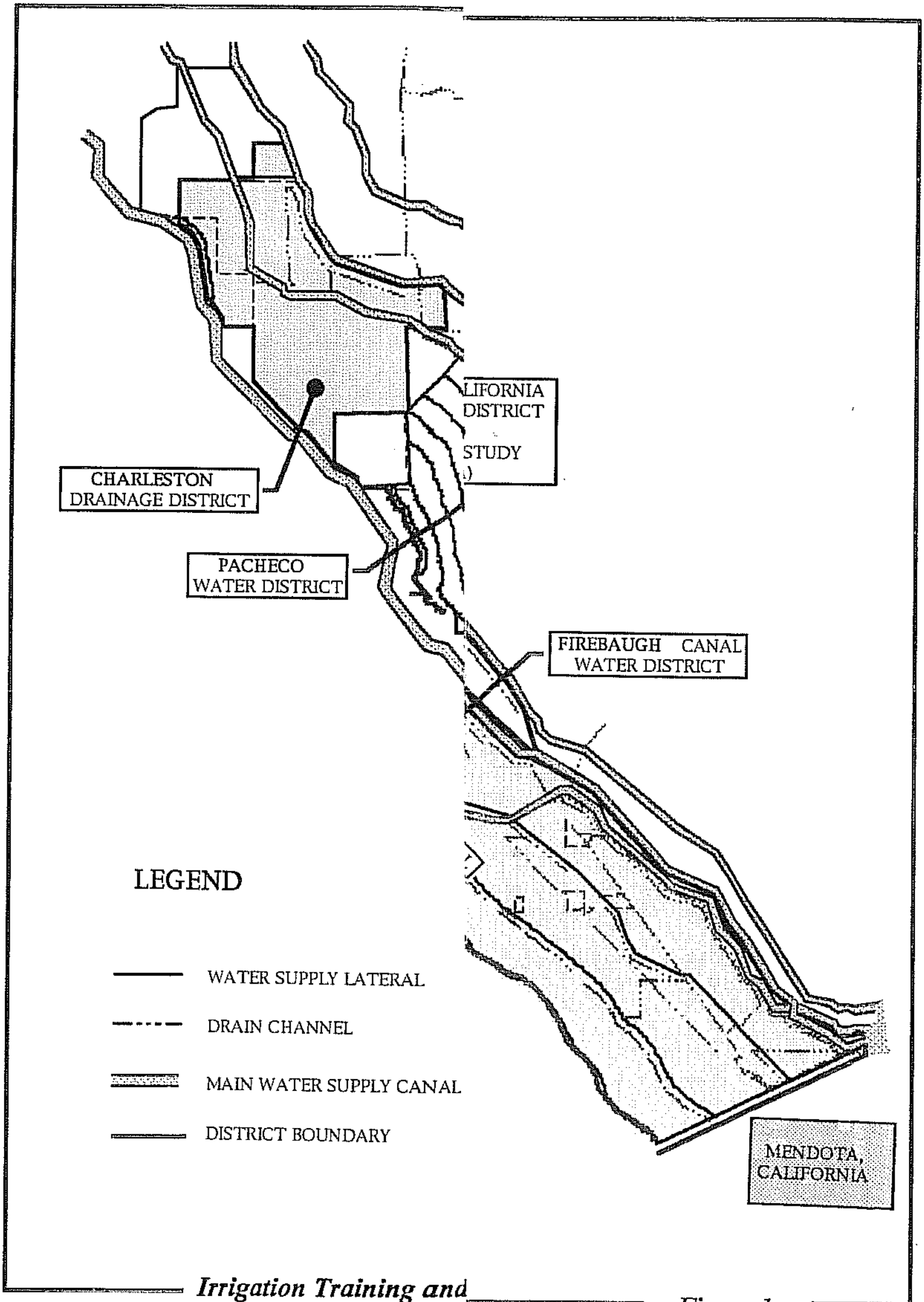
RE-USE OF SURFACE RUNOFF AND SUBSURFACE DRAIN WATER

INTRODUCTION

This project analyzed 6 subareas of the Grassland Basin roughly representing 80,000 acres on the west side of the San Joaquin Valley near Firebaugh, California. The subareas are identified in this report as Broadview Water District (BWD), Central California Irrigation District (CCID-Camp 13), Charleston Drainage District (CDD), Firebaugh Canal Water District (FCWD), Pacheco Water District, (PoWD), and Panoche Drainage District (PDD). These areas are shown on **Figure 1.** The time span was from 1981 through 1992. This first section describes some of the actions districts and individual growers have implemented with regards to the reuse of surface runoff and subsurface flows.

Surface runoff from agricultural fields and water collected in subsurface drains have been the focus of much attention among farmers, district staff, and regional water quality authorities in recent years. Surface runoff, also called tailwater, is often generated when siphon tubes, or gated pipes are used to irrigate with furrows or bordered checks that may be 1/6-mile to 1/2-mile long. Sprinkler irrigation systems usually generate less tailwater than surface methods, but a poorly managed sprinkler system can result in surface runoff. The quality of surface runoff is generally equivalent to the quality of water delivered to the field, but the runoff usually contains silt and nutrients that are collected from the soil surface.

Water collected in subsurface drains on the west side of the San Joaquin Valley often contains a mixture of salts, boron, selenium, and other elements. Some of these elements, including boron and selenium, occur naturally in the Valley's soils but are harmful to plants or wildlife at high concentrations. Selenium concentrations in subsurface drain water have been a concern to state and regional water quality authorities who are responsible for protecting water quality in the San Joaquin River and its tributary sloughs. The Regional Water Quality Control Board for the Central Valley Region of California has called on farmers in the region to reduce the volume of subsurface drain water and the associated loads of boron and selenium that are discharged into the River and its tributary sloughs each year.



Irrigation Training and

Figure 1

ƆN AND DRAINAGE STUDY
IN STUDY AREA

Although the principle target of water quality authorities in the San Joaquin Valley is subsurface drain water, it is not possible to separate this issue from the management of surface runoff because both types of water are often mixed and transported in the same drainage ditches. In fact, surface runoff helps to reduce the concentrations of boron and selenium in drainage ditches, but it also contributes to the volume of water and the loads of salt and selenium in those ditches. It may be desirable to reduce the volume of surface runoff moving through regional drainage ditches in order to reduce the total volume of drainage water requiring disposal or treatment, but this will cause the concentrations of salt and selenium in those ditches to increase.

Many farmers in the San Joaquin Valley have already begun reducing tailwater volumes to a very small portion of the total water delivered to farm fields in order to maximize the area that can be irrigated with limited water supplies. Many of these farmers have begun using shorter furrow lengths and shorter irrigation set times to improve distribution uniformity. They have also hired night irrigators to monitor water deliveries carefully through the night. Other farmers have begun using sprinkler irrigation systems to maximize the value of limited water supplies. The most significant factor in tailwater reduction has come from installation of on-farm tailwater return systems. All of these improvements in farm-level water management have contributed to significant reductions in surface runoff in recent years.

The motivation to manage water deliveries carefully is likely to remain in place during the near future, as water supplies will continue to be restricted and as the value of water increases both directly, due to increases in price, and indirectly, through water marketing opportunities. Farmers who have purchased sprinkler systems will continue to use them and farmers who have implemented more intensive management of surface irrigation systems will likely continue these practices. Hence, the volume of surface runoff entering district-level and regional drainage ditches will continue to be less than the volumes observed during the mid-1980's. However, there will still be surface runoff (tailwater) in most of these ditches because it is often expensive to separate surface runoff (tailwater) from subsurface drain water (tilewater) at the farm level.

This outlook for tailwater volumes in the region has important implications for policies regarding the re-use and disposal of subsurface drain water. For example, if tailwater volumes will be declining over time, the concentrations of salt and selenium in regional drainage ditches will be increasing, regardless of the volume of subsurface drain water in those ditches. This will make the commingled drainage water less desirable for re-use among farmers who have the opportunity to use the drainage water at some point along the regional drainage ditches. In addition, the drainage water that enters the San Joaquin River or its tributary sloughs will contain higher concentrations of salt and selenium than were present when there was a significant tailwater component in the drainage water.

However, it is probably desirable to maintain these reductions in tailwater volumes because they result from improvements in water management that are necessary to maximize the value of limited water supplies. In addition, the reductions in tailwater volume will lead to reductions in the total volume of drainage water requiring treatment or disposal. This may result in significant cost savings when regional drainage water treatment or transportation facilities are constructed in the future.

Specific farm-level and district-level strategies for re-using surface runoff and subsurface drain water are described in the following sections of this report. Throughout that discussion, "surface water" and "tailwater" are used interchangeably, while "subsurface drain water" refers specifically to the water collected in subsurface drains. The term "drainage water" is used to describe the commingled mixture of tailwater and subsurface drain water or "tilewater" that flows through farm-level, district-level, and regional drainage ditches.

FARM-LEVEL RE-USE STRATEGIES

There are several activities that may be undertaken by farmers and by irrigation or drainage districts to re-use subsurface drain water. In most cases, there will be "economies of scale" or "economies of concentration," that make district-level re-use of subsurface drain water more attractive than farm-level re-use. However, in the interest of completeness, farm-level re-use activities are presented here. In principle, farmers can re-use subsurface drain water that is generated as a result of their irrigations in one of four ways:

1. Maintain a high water table that can be used by plants to satisfy a portion of crop water requirements (sub-irrigation).

   This practice is not widely accepted in the Valley because farmers are concerned about allowing saline drainage water to accumulate in the crop root zone. In addition, most of the existing drainage systems were installed to provide rapid and effective removal of saline water. The subsurface drain lines in these systems were installed on a slope to facilitate water movement from the upper end of a field to a collector system at the bottom of a field. It is difficult to achieve uniform sub-irrigation when the drainage lines are installed with such a slope.

Farmers are concerned that efforts to sub-irrigate with saline water may cause salt accumulation problems in lower portions of a field before the upper part of a field receives adequate water. It may be possible to modify existing drainage systems to provide sub-irrigation by cutting drain lines and installing regulator valves at specific linear intervals. Field demonstrations are required to examine the potential of this approach.

Sub-irrigation can also be accomplished by planting deep-rooted crops and allowing these crops to utilize water in the shallow water table. During the drought, many fields of alfalfa seed in the Broadview Water District were irrigated only once or twice per year. A large portion of the crop water requirement of these fields was satisfied by the shallow water table.

2. Collect subsurface drain water in a sump and deliver the water to an adjacent field, via gravity flow.

   Much of the subsurface drain water generated in the Grassland Drainage Basin is collected in sumps that are connected to subsurface collector lines in one or more fields. When the water in a sump reaches a pre-determined level, drain water is pumped automatically from the sump and into a ditch that carries the drain water away from the field. At present, most of these ditches carry both subsurface drain water and surface runoff from many farms in a district.

   It would be possible to pump drain water from a sump into a farm-level ditch to carry the drain water to another field, but the drain water would need to be blended with surface runoff or fresh water before it is used to irrigate corps. The ratio of fresh water to drain water that would be required at the farm level may be quite large, particularly if the farmer is generating only a small amount of surface runoff. It may also be difficult to schedule irrigations on adjacent fields in a manner that allows drain water from one field to be used on another field, at the same time. This will be particularly difficult when a farmer has several fields of different crops that are irrigated at different times during the season.

3. Collect subsurface drain water in a sump and re-circulate the water to the point where fresh water deliveries are received, and then blend the drain water with the fresh water deliveries.

   This strategy would not require farmers to coordinate irrigation on adjacent fields, but the drain water would need to be blended with fresh water before re-use occurs. Farmers could install a single system to pump both drain water and surface runoff back to the upper end of a field, but with diminished tailwater volume, sufficient dilution of the subsurface drain water will be difficult. Also, if 100% the tile water was recirculated, it appears that the root zone salinities would become so high as to be toxic to some crops such as tomatoes.

4. Collect subsurface drain water in a sump and deliver it to a field of eucalyptus trees or some other crop that is planted for the purpose of receiving subsurface drain water.

   This strategy is currently being practiced by at least two farmers on the west side of the San Joaquin Valley and additional farmers may adopt this practice in the future. The goal is to dispose of drain water by irrigating a crop that is not affected by salt accumulation into the soil. Eucalyptus trees are expected to be very salt tolerant and they may even be harvested for sale as firewood. However, the market for firewood in the San Joaquin Valley may be limited and farmers are concerned about the long-term implications of applying large amounts of saline drain water to a portion of their farmland. There are also many unsolved problems related to frost damage to the trees, final disposal of the more concentrated drain water, and the bioaccumulation and ultimate destinations of various salt components.

All of these drain water re-use strategies are physically feasible at the farm level, but they may not be economically feasible, given the cost to modify existing subsurface drainage systems and the difficulty of blending saline drain water with limited surface water supplies. For these reasons, most current re-use of drain water in the region is accomplished at the district level, where large volumes of fresh water and tailwater are available for dilution. In addition, districts are able to blend drain water with surface water supplies when delivering water to several farmers during a given time period. This provides districts with greater flexibility in blending drain water than is possible for a single farming operation.

Another form of farm-level re-use occurs when farmers located downslope of regional or district-level drainage ditches choose to use water from those ditches for irrigation. These farmers may blend the drainage water with their own fresh water supplies, or they may use the drainage water directly for irrigation. Farmers who use drainage water in this manner will usually monitor the electrical conductivity of the drainage water very carefully and will make decisions daily regarding drainage water use and blending. Many farmers in the Grassland Drainage Basin who re-use drainage water have become very skilled in the use of portable electrical conductivity meters. These farmers check the conductivity of drainage water and delivery water in their farming operations regularly.

DISTRICT LEVEL RE-USE STRATEGIES

Irrigation and drainage districts can promote the re-use of subsurface drain water among district farmers and they can also provide re-circulation services that may not be economically feasible at the farm level. For example, districts can collect subsurface drain water from a large number of farms in a series of collector drains that carry drainage water, via gravity, to points of low elevation in the district. These drains may carry both subsurface drain water and surface runoff, or they may carry only subsurface drain water. The district, after collecting the subsurface drain water, can determine the optimal district-level strategy for re-use or disposal of the drain water.

The set of policies available to districts, regarding subsurface drain water can be summarized as follows:

- Accept no subsurface drain water and no surface runoff from farmers in the district,
- Accept only subsurface drain water, and require farmers to eliminate or re-use all of their surface runoff,
- Accept both subsurface drain water and surface runoff in a single set of district drainage ditches,
- Accept both subsurface drain water and surface runoff in separate ditches, to maintain separation of surface runoff and subsurface drainage water,

- Re-use the drainage water by blending it with fresh water deliveries at one or more locations in the district, or
- Discharge the drainage water into regional drainage ditches that carry the water to the San Joaquin River or its tributary sloughs.

District managers will likely choose some combination of these policies in selecting an optimal strategy for managing drain water volumes and the salt concentration in water deliveries. For example, it may be optimal to blend significant amounts of drainage water with fresh water deliveries during some months and it may be optimal to discharge drainage water in order to maintain high-quality water deliveries in other months. The existing design of district drainage ditches and delivery systems may also place constraints on the extent to which a district can recirculate drainage water in a given time period, as well as on where in the district the irrigation water can be re-applied.

All of the districts that reuse subsurface drain water in the Grassland Drainage Basin have adopted policies describing the maximum concentration of total dissolved solids that will be permitted in water deliveries to farmers. These values vary among districts, but are generally in the range of 1,000 to 1,400 parts per million of total dissolved solids. District staff monitor the salt concentration in water deliveries on a daily basis and they adjust blending ratios, as needed, to maintain delivered water quality within the stated policy objective.

Districts delivering blended water must coordinate blending ratios to accommodate farmers using sprinklers to germinate young plants or to irrigate melons and tomatoes during early-season irrigation events. Sprinklers place water directly on the leaves of plants. Salt can damage the plants as the water evaporates and leaves the salt on the plant surface. Districts may need to provide better quality water during specific irrigation events or to farmers using sprinkler systems, in order to maintain farm-level support of the district's drain water re-use strategy.

CURRENT RE-USE ACTIVITIES IN THE GRASSLAND DRAINAGE BASIN

Farm-level and district-level re-use of surface runoff and subsurface drain water have increased significantly in recent years in the Grassland Drainage Basin. Much of the motivation for this increase in re-use has been generated by significant reductions in surface water supplies to federal irrigation districts in the region. Persistent drought conditions resulted in a 50% reduction in surface water supplies during 1990 and 75% reductions in 1991 and 1992. Water supplies were reduced by 50% in 1993, due to restriction on the pumping of water through the Delta formed by the Sacramento and San Joaquin Rivers. Those restrictions were imposed due to implementation of the Endangered Species Act. Additional motivation has been provided by increased prices for surface water supplies, uncertainty regarding surface water allocations, and a desire among farmers and district mangers to achieve water quality objectives in the San Joaquin River and its tributary sloughs.

Some of the increase in re-use at the farm level is due to specific policies and programs implemented by irrigation and drainage districts, while some of the increase is due to farm-level incentives regarding water availability and cost. For example, farmers in the Panoche Drainage District are not allowed to discharge surface runoff into district drainage ditches and, therefore, must either eliminate surface runoff or re-use the runoff on the original field or on a field located downslope from where the runoff is generated. The small volume of surface runoff that is currently collected by the Panoche Drainage District will be reduced even further, as the district plans to enforce its tailwater policy more aggressively in the future.

The tailwater policy adopted at the Panoche Drainage District allows that district to collect and manage a smaller total volume of drainage water by removing surface runoff from district drainage ditches. Over time, the district will have only subsurface drain water in its drainage ditches and the district manager will be able to determine the optimal combination of volumes for re-use and disposal, throughout the year, without needing to accommodate large volumes of surface runoff in the drainage system.

None of the other districts in the Grassland Drainage Basin has a specific tailwater policy, but several farmers in those districts have begun re-using surface runoff to augment their contractual water allocation. One relatively large farming operation in the Charleston Drainage District installed a re-circulation system that captures both surface runoff and subsurface drain water in a single re-circulation basin. The commingled drainage water can then be pumped uphill and blended with fresh water supplies at one of two locations where the farmer receives his water deliveries. This system was used often during 1992 and 1993 to increase that farmer's water supply.

The Charleston Drainage District does not provide any district-level re-circulation of drainage water, largely because it is not a water supply district and it does not have the facilities to accomplish a blending task. However, the district manager does work with farmers to coordinate the re-use of commingled drainage water at several points along the district's principal drainage ditch. In addition, the district has assisted farmers in the construction of tailwater recovery ditches to promote the re-use of surface runoff. The district has also constructed diversion structures that allow farmers to separate the surface runoff and subsurface drain water in locations where this is feasible.

At least two farmers in the Charleston Drainage District are able to utilize some of the drainage water that flows through the district's drainage ditch, at certain times of the year, provided that the electrical conductivity is within acceptable limits. Coordination of re-use activities among farmers in Charleston is sometimes required, to maximize the potential for re-using drainage water, because the district is relatively small and the actions of one farmer can have a significant impact on the volume and concentration of water flowing in the district's drainage ditch.

Two farmers in the Broadview Water District have installed field-level tailwater re-circulation systems in recent years, but no farmers have begun to reuse subsurface drainage water directly from sumps located on their farms. At the present time, Broadview collects all surface runoff and subsurface drainage water in district ditches and the district manager determines the optimal strategy for blending some of the drainage water with fresh water deliveries during some portions of the year and discharging a portion of the drainage water at other times.

District-level re-use of tailwater and subsurface drain water is also provided in the Firebaugh Canal Water District and in the Pacheco Water District. In Firebaugh, surface runoff and subsurface drain water from one portion of the district are pumped into one of the district's water delivery canals, where the commingled drainage water is blended with fresh water before being delivered to farmers at lower elevations in the gravity-flow delivery system. The Pacheco Water District collects surface runoff and subsurface drain water from all farmers in the district and recirculates the commingled drainage water through its water delivery system. At the present time, Pacheco is not able to distribute recycled drainage water throughout the entire district, but structural improvements that will increase the land area served by the recirculation system will be constructed in the near future.

OPPORTUNITIES AND CHALLENGES

The significant increase in the re-use of surface runoff and subsurface drain water, at both the farm-level and district-level in the Grassland Drainage Basin, have provided farmers and districts with much-needed augmentations of contractual water supplies and have resulted in significant reductions in the volume of drainage water discharged from districts to the San Joaquin River and its tributary sloughs. Water supplies will likely be constrained in the region during the near future, as environmental issues regarding the Delta remain unresolved and as state and federal agencies continue to restrict the use of Delta pumps during critical months. The desire to achieve regional water quality objectives will also remain in place, although farmers and districts realize that reductions in drain water volume may not increase the probability that the Mud Slough (North) and Salt Slough water quality objectives can be met.

Some re-use of surface runoff and subsurface drain water will continue to occur in the Grassland Drainage Basin in the 1994 crop year, for the reasons noted above. However, the amount of re-use that occurs during 1994, and during later years, will be determined by:

- The impact that re-use has on long-term crop productivity,
- The current farm-level outlook regarding water supply, drainage issues, and regional water quality objectives, and
- The ability of farmers and districts to address the technical and financial constraints that limit the efficient re-use of subsurface drain water.

In addition, the amount of re-use that occurs in the future can be influenced by specific incentive programs or drainage discharge policies adopted by the Regional Water Quality Control Board.

The previous six years have provided farmers, district managers, and regional water quality authorities with an opportunity to observe the short-term challenges for re-using subsurface drain water. Many farmers have also begun to observe or to report on the potential long-term impacts of re-using subsurface drain water in the Grassland Drainage Basin. Several themes describing the opportunities and challenges to re-using drainage water have emerged during interviews with farmers and district managers in the region.

The managers of the Broadview Water District, the Central California Irrigation District, the Charleston Drainage District, the Firebaugh Canal Water District, the Pacheco Water District, and the Panoche Drainage District were interviewed during July and August of 1993. All of the managers have been involved with, or have observed, the re-use of surface runoff and subsurface drain water, at either the farm level or the district level, during recent years. Several of the managers who have developed significant experience in managing a re-use program at the district level have described some of the constraints they perceive regarding the short-term and long-term viability of reusing subsurface drain water.

One of the principle concerns expressed by all of the managers interviewed in this study is the difficulty and expense involved in distributing recycled drainage water throughout a large portion of an irrigation district. Several of the managers reported that their current water delivery and return systems do not permit them to deliver recycled drainage water to all of the lands that may have generated the drainage water. In some cases, the small size of the area that can receive recycled drainage water creates both an equity issue and an efficiency issue that the manager must resolve.

In some districts, when drainage water generated in one portion of the district is recycled and delivered to farmers in another portion of the district, the farmers receiving the drainage water have expressed displeasure with the recycling policy. Their recommendation is that the farmers generating the drainage water should be the farmers who receive the recycled drainage water in their water deliveries. From an efficiency perspective, it may not be possible to achieve the desired level and uniformity of salt concentration in water delivered to farmers, when the area for distributing the drainage water is limited. In some cases, farmers located closer to the point where drainage water is mixed with fresh water receive water with a higher salt concentration than do farmers located further along the distribution system.

The equity and efficiency issues regarding drainage water re-use are short-term issues that district managers have attempted to address through careful adjustment of water volumes and concentrations in response to specific requests from farmers receiving recycled drainage water. In the long-term, district managers suggest that expensive construction projects may be required to build new recirculation facilities for moving drainage water to all portions of an irrigation district. This would permit maximum blending of drainage water with fresh water supplies and would appear to be more equitable from the perspective of farmers in some portions of the district. However, the managers also described a reluctance to undertake such construction projects, given the existing uncertainty regarding water supply, the drainage situation, and environmental issues in the region.

Many of the managers also described the issue of maintaining consistency among water management objectives and drainage reduction goals, particularly as these goals and objectives become embodied in district-level policies that affect farm-level activities. For example, several managers reported that the recent increase in sprinkler use among farmers has resulted in a need for better quality water from irrigation districts, just as districts have increased their re-use of subsurface drain water. Farmers germinating young crops with sprinklers require high quality (low salt) irrigation water, to prevent damaging the young plants. Therefore, district managers must be careful not to deliver high-salt irrigation water during times when farmers are sprinkling young plants. This issue was not as critical before farmers began using sprinkler systems.

Some of the managers also reported a concern regarding the linkage between water quality objectives in the San Joaquin River, Mud Slough (North), and Salt Slough, and the volumes and concentrations of drainage water released at district discharge outlets. In particular, the managers perceive a lack of information regarding the specific strategies that districts should pursue in managing subsurface drain water. Strategies designed to reduce drain water volumes and loads will likely result in higher concentrations of boron and selenium at district discharge outlets. Thus, while the probability of achieving water quality objectives in the San Joaquin River will be increased, the concentrations of boron and selenium in Mud Slough (North) and Salt Slough will also be increased.

During the years 1986 through 1992, several districts had achieved significant reductions in drainage water volume through aggressive recycling programs conducted to augment limited water supplies. However, in general, the average concentrations of salt, boron, and selenium in the drainage water released by districts have either remained constant or have increased.

District managers realize that reductions in drainage water volume and loads in regional ditches will increase the probability of achieving water quality objectives in the San Joaquin River, at the cost of higher concentrations of salt, boron, and selenium in regional drainage ditches. This will make it more difficult to achieve water quality objectives in the tributary sloughs, where there is very little dilution water available during the irrigation season. The managers also realize that the water quality objectives in the sloughs may not be achievable as long as there is <u>any</u> volume of drainage water in the system. Hence, there is good support among district managers for maintaining reductions in drainage water volume and loads, but there is also some reluctance to pursue achievement of the water quality objectives in the tributary sloughs.

Several farmers operating in the Grassland Drainage Basin were also interviewed in this study, to receive input regarding the short-term and long-term implications of re-using subsurface drain water. One of the farmers has been re-using drainage water for more than six years to augment limited water supplies. That farmer reports no yield effects on cotton and sugar beets, to date, but he does report noticeable damage on a field of alfalfa hay. This is the first year he has noticed the damage, but he feels this is the beginning of permanent difficulty with his recycling program, unless he is able to leach salts from the soil in the near future.

This same farmer reports an important relationship regarding water volume and quality when re-using subsurface drain water. In recent years, he has had to increase the volume of water delivered to his fields, as the quality of water has declined. Continued application of high-salt water to his fields has resulted in saline soils that restrict the ability of plants to extract water. Therefore, he must keep the soils more moist than usual in order for plants to extract the water. His average water deliveries to cotton, alfalfa, and sugar beets have increased, even though he is re-using the subsurface drain water to augment his limited water supply. It should be noted that although continued recirculation of tile water will require both a high leaching fraction and more frequent irrigations (to keep the soil salts more dilute), such management generally requires a modification of the irrigation system design or irrigation duration to prevent gross over-irrigation. If, for example, hand more sprinklers are used more frequently, the hours per application should be reduced accordingly. With furrow irrigation, more frequent irrigations may require the use of shorter furrows, alternate furrow irrigation, torpedo compaction, or other measures to reduce the depth infiltrated per irrigation.

Another farmer operating in the region reports actual crop damage in 1993 when using sprinklers to irrigate young cotton plants. The farmer was blending subsurface drain water and surface runoff with fresh water, but the resulting salt concentration was high enough to damage the young plants. He replaced the sprinklers with siphon tubes when he noticed the damage. The remainder of the field was taller and looked healthier in late July, when the interview with this farmer was conducted.

A farmer operating in another irrigation district reported damage to a young tomato crop, while sprinkling the plants with irrigation water measuring about 1,000 parts per million in total dissolved solids. The farmer complained about water quality to the water district manager, who explained that the district's current recycling policy allowed for water to be delivered at that concentration. However, the farmer was concerned that this policy was not consistent with motivating farmers to use sprinkler irrigation systems and suggested that better water quality was required to operate sprinklers successfully. It is possible that events such as these occurred in many irrigation districts during the drought, as district managers worked to augment their water supplies through intensive recycling efforts.

Some farmers in the Grassland Drainage Basin are able to use commingled drainage water as a supplement to limited water supplies, provided that the salt and boron concentrations in the drainage water are not excessive. One such farmer is located along a district drainage ditch that carries commingled drainage water past fields that he rotates in cotton, alfalfa hay, and corn. During past years, the salt concentration has been reasonable and he has been able to use significant quantities of water from the drainage ditch. During the most recent two years, however, farmers in the district have increased their re-use of surface runoff, resulting in a higher proportion of subsurface drain water in the district drainage ditch. As a result, the salt concentration has increased and opportunities to reuse the commingled drainage water have been reduced. At a minimum, the farmer must now use a larger amount of fresh water to dilute the drainage water before delivering it to crop fields.

The farmer providing this observation suggested that farmers discharging drainage water into district ditches should be required to discharge both surface runoff and subsurface drain water, or to re-use both components on their farm, rather than discharging only the subsurface drain water. The farmer felt that this policy would motivate all farmers to pay greater attention to the impacts that their water management practices have on farmers located along district drainage ditches and in other areas of an irrigation district.

The farm-level observations reported in this study are consistent with the comments of district managers regarding the limited opportunities for re-using subsurface drain water efficiently and equitably, given the existing water delivery and drain water collection systems. The large expense required to construct ideal facilities for maximizing the potential re-use of drain water will not be allocated by districts, given current economic conditions and uncertainty regarding water supply and drainage issues. Districts and farmers will likely continue to pursue short-term solutions to district-wide drainage management issues until a clearer plan is presented to them regarding their individual or district roles in achieving regional water quality objectives.

SECTION 2

DRAINAGE

OVERVIEW

Long-term success for farmers in the Grassland Drainage Basin might be defined as "maintaining acceptable agricultural profitability while meeting the water quality standards in the San Joaquin River." This success will depend on the drainers' ability, in the Grassland Area, to control the timing and amount of salt movement to the San Joaquin River. This ability will be affected by:

- Modifications to on-farm tile drain systems and irrigation practices that could possibly reduce the pickup of salts, especially selenium.
- Individual district strategies for disposal of drainage water.
- Cooperation among the districts in jointly meeting water quality standards.

Unblended agricultural drainage that leaves a district's boundaries will almost always be of worse quality than the water quality standards of the San Joaquin River. Thus, drainage water must be blended with better-quality water. There are two possible sources for blending water:

1. The natural flows of the San Joaquin River
2. High quality drainage water which leaves a district

The amount of high quality water available for blending is the "assimilative capacity" of a district.

Future actions by various regulatory agencies may restrict the amount of San Joaquin River water which can be used by districts to blend with their drainage water. If this occurs, districts will have to use the assimilative capacity of their own irrigation water supply. In either case, districts can develop a management strategy if they have internal control of drainage amounts, qualities, and destinations. Without internal control, meeting water quality standards will hinge on the variable assimilative capacity of the San Joaquin River, or on unplanned, and possibly excessive releases of district irrigation water. Irrigation water may or may not be available when needed, especially considering demand by district farmers during critical crop growth periods.

DRAINAGE DECISION TREE

The decision tree for a district's drainage water control/release strategy is made up of five different policy levels: Acceptance, Separation, District Level Recycling, Holding, and Assimilation Water. Each of these levels will be discussed along with their implications. **Table 1** is a listing of these drainage policies and a brief description of each policy. A **Drainage District Decision Tree** which is shown in **Figure 2** shows how these policies interact.

Table 1
District-Level Drainage Policies

Policy	Description
Acceptance	Decision by districts to accept or deny drainage or surface water into district surface drains.
Separation	If a district accepts both tile water and tailwater, the next policy decision is whether or not to keep them separate.
Recycling	The next policy decision is whether or not a district will recycle any of water back into the supply.
Holding	Storage of drainage water could be required to meet water quality standards.
Assimilation	Blending of the drain water with better quality water to meet water quality standards.

ACCEPTANCE

The Acceptance level of the decision tree involves the decision by districts to accept or deny drainage water into district surface drains. Irrigation can result in surface runoff (tailwater), subsurface drainage collected in tile drain systems (tile water), or both. A district's drainage acceptance policy depends on:

- **Timing.** A district may have specific times of the year when it accepts either tile water or tailwater. It may always refuse to accept any drainage water.
- **Quality.** There may be some minimum (or maximum) water quality that is required before drainage water is accepted by a district.

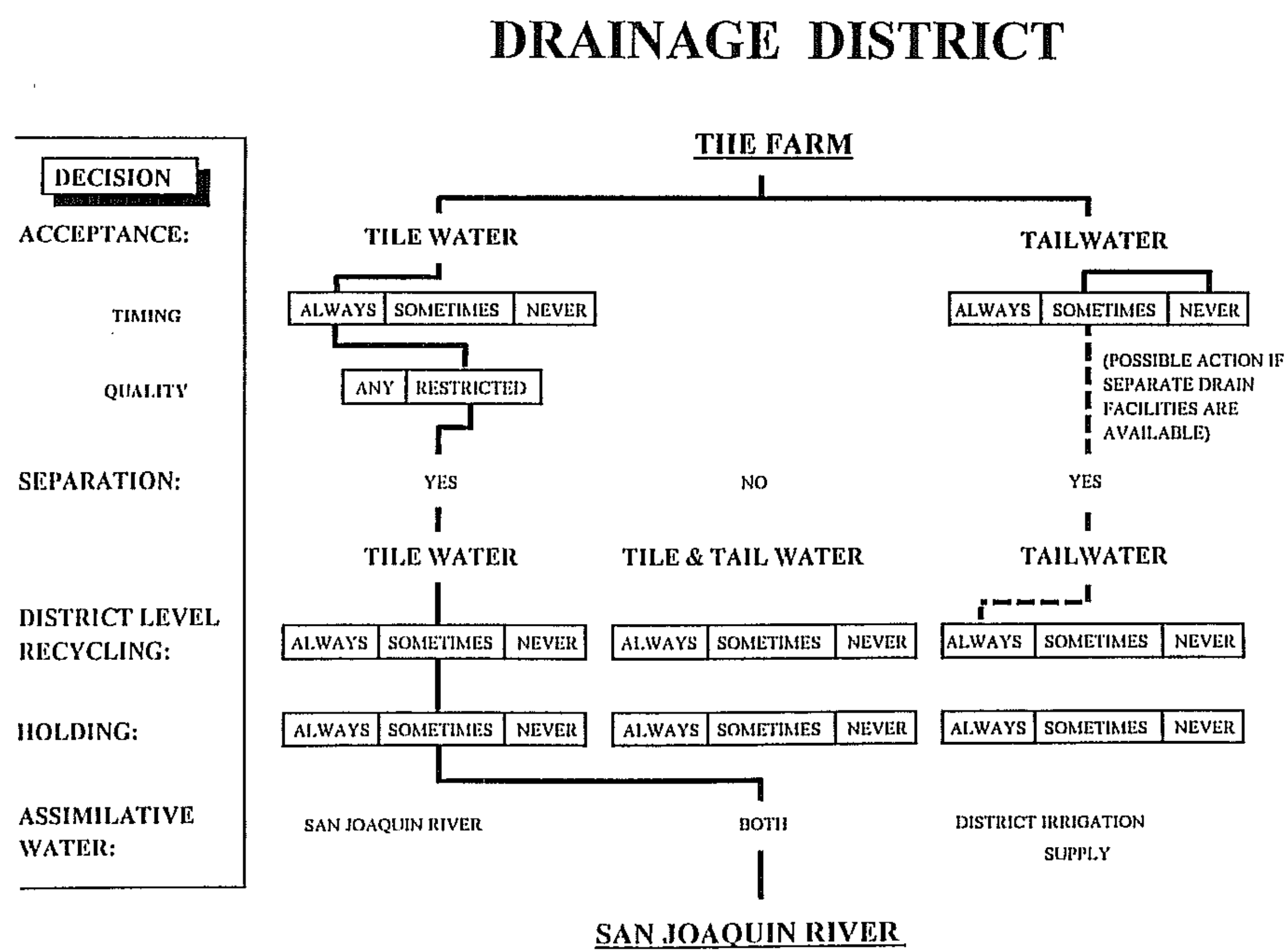

DRAINAGE DISTRICT
THE FARM
DECISION
ACCEPTANCE:
TIMING
QUALITY
SEPARATION:
DISTRICT LEVEL RECYCLING:
HOLDING:
ASSIMILATIVE WATER:
TILE WATER
TAILWATER
ALWAYS
SOMETIMES
NEVER
ANY
RESTRICTED
(POSSIBLE ACTION IF SEPARATE DRAIN FACILITIES ARE AVAILABLE)
YES
NO
YES
TILE WATER
TILE & TAIL WATER
TAILWATER
SAN JOAQUIN RIVER
BOTH
DISTRICT IRRIGATION SUPPLY
SAN JOAQUIN RIVER

Figure 2

Tailwater salt and selenium concentrations are considerably lower than those in tile water. The acceptance of tailwater into surface drains along with tile water dilutes the tile water and results in larger water volumes than if tile water alone was accepted. Four possible reasons for denial of tailwater are:

1. It minimizes the handling costs, power for pumping, and pipeline/ditch sizes.
2. It may be the only way of separating tile water and tailwater.
3. It will minimize the required facility size if utilizing external storage.
4. Nematodes and viruses may be spread throughout the district if tailwater from an infested field is later recycled through district canals.

In the San Joaquin Valley, tailwater which is recycled on-farm is not considered to contribute significantly to the salt loading of the soil profile.

Although a district can refuse to accept tailwater, it cannot do so indefinitely with tile water. A grower cannot recirculate his own tile water indefinitely. However, it may be a district policy to set a minimum total salinity level of the tile water before acceptance. There are at least three reasons for such a policy:

1. This would again minimize handling costs to the district as it would reduce the volume of drainage water in the system.
2. It may be district policy to store salts internally (ie., in the soil or in the shallow groundwater system) when no assimilative capacity is available.
3. If externally storing salts is part of a district's strategy, this will tend to concentrate salts in solution and reduce the required size of the storage facility.

On-farm recycling of tailwater requires additional capital expenses by the individual farmer. There may be a valid argument that district level recycling is more cost effective. However, if a district institutes tiered water pricing, as many districts in the Grassland Area have done, on-farm recycling will almost always be more economical because the cost of recycling water on-farm is generally less expensive than purchasing recycled water later at a higher price. On-farm recycling also enables farmers to purchase less water from the district.

SEPARATION

If a district accepts both tile water and tailwater the next policy decision is whether or not to keep them separate. (If the Acceptance policy is not to take tailwater, the Separation policy is automatic: tile water and tailwater are separated.) Although separation of tile water and tailwater requires dual drainage facilities, it provides better control over the movement of salts into, through, and out of the district than a mixed drainage system. Two benefits of separating tile water and tailwater are:

1. Minimization of the size of any holding facility, as storage would only be for tile water.
2. Increased control over the resulting water quality of delivered irrigation water if a district is recycling its drainage. The district may decide to recycle only the better quality tailwater.

DISTRICT LEVEL RECYCLING

The next policy decision is whether or not a district will recycle any of its drainage water back into the irrigation supply. If tile water and tailwater are kept separate, a district may opt to always recycle tailwater and never recycle tile water. It may be more realistic for the district to decide to sometimes recycle tailwater and to sometimes recycle tile water. Tailwater may not be recycled if there is no demand for irrigation water. Tile water may be recycled if the quality is at some level (and irrigation demand is at some level).

District level recycling will certainly increase the costs of some district operations. However, benefits include:

- A reduction of the required size of any external holding facility.
- An increase in the IE of the district, helping to minimize total water costs to the farmers by reducing the amount of State Water Project or Central Valley Project water used by the district.
- A reduction in the amount of water imported into a district reduces the amount of salt imported.

As with on-farm recycling of tile water, district level recycling provides a way of temporarily (less than one month) storing salts within the soils of fields when assimilative capacity is not available. Thus, the drainage system becomes a closed loop from irrigation water, to soil water, to drainage water, and back to irrigation water. Just as recycling of tile water on-farm cannot continue indefinitely without a decrease in productivity, neither can district level recycling of tile water continue indefinitely unless there is sufficient natural drainage out of the district.

HOLDING

If a district does not recycle drainage water there are only two other options:

1. The drainage water flows immediately to the San Joaquin River.
2. The drainage water is temporarily stored in some type of holding facility (reservoir).

Storage of drainage water would be required if there was no assimilative capacity available to meet water quality standards in either the San Joaquin River or in the district.

In at least two cases in the study area, drainage water flowing to the San Joaquin River is presently being picked up for irrigation by farmers outside of any water or drainage district. Unless this use can be consistently regulated it may not be justifiable as part of a district's policy decisions. The study assumed that once drainage water leaves the control of a district, it is destined for the San Joaquin River.

External holding is an expensive option. There are capital and maintenance costs for the facility, environmental concerns, and the basic problem of finding inexpensive, relatively flat land to use for the facility in the midst of a highly productive agricultural area. However, external holding does provide the quickest and simplest option for storing salts in order to meet water quality standards when the assimilative capacities constantly vary.

ASSIMILATION WATER

Agricultural drainage will almost always be of worse quality than water quality standards. This is especially true of tile water. Thus drainage will generally have to be blended with better quality water to meet water quality standards. Blending water can come from the fresh water flows of the San Joaquin River or irrigation water supplies. For assimilation purposes, tailwater can be considered part of irrigation supplies because of its relatively high water quality. Thus a policy must be formulated for choosing which assimilative capacity is used.

Note that if the district which discharges drainage is a "pure" drainage district (as opposed to a water or irrigation district) it may not have access to fresh water supplies. In these cases, some type of agreement will be needed with associated member farmers or water supply districts. A prime example of this situation is the CDD.

Increased use of a district's assimilative capacity will always require some investment. If deep wells are in place, a district may opt to increase groundwater pumping. Groundwater pumping will almost always be more expensive than surface water supplies. Groundwater quality in many areas is suspect.

If there are no deep wells in a district, surface irrigation water supplies must be used as a source of a district's assimilative capacity. This capacity may be increased in the future for two reasons:

1. On-farm IE may increase.
2. Cropped acreage may decrease.

If a district must select between these two options, improvements of on-farm IE may be preferable. Improvements in on-farm IE will usually cost money. However, in some cases there is a possibility of actually improving profitability due to a reduction in labor, energy, and fertilizer costs, as well as the possibility of increased crop quality or yield. In general, reducing cropped acreage will only reduce profits, assuming there are no other changes in management.

The question related to the assimilative capacity of the San Joaquin River is: "What portion of the total assimilative capacity of the San Joaquin River is claimed by each individual district, and by the districts as a group in relation to other drainers to the San Joaquin River?." Some possible bases for the division of the San Joaquin River's assimilative capacity are, irrigable acreage, historical drainage discharges, or historical salt loads. The extent to which each district can claim the San Joaquin River's assimilative capacity will ultimately be a political/regulatory decision.

INTERRELATIONSHIPS OF DECISIONS

A district's drainage policy decisions are interrelated at all levels. The following issues must be considered when determining a district's drainage policy:

- Tile drainage must be transported off the farm at some time unless adequate natural drainage exists. This does not necessarily mean the first time it is collected.
- External facilities are a means of storing salts when the assimilative capacity of either the San Joaquin River or the district is low. Minimizing the size, and thus costs, of the facility require concentrating the salt solution as much as possible.
- The maximum EC of drainage water occurs when the soils and shallow groundwater of the entire district are at the maximum acceptable salinity (assuming all farmers are irrigating with correct leaching fractions).
- Immediate acceptance of tile water and district level recycling will eventually balance the salt load in individual fields throughout a district, given that the blended water is equally available to all lands in the district. More salts will be imported than exported to those fields with low salinity. Less salts will be imported than exported in fields with high salinity. This assumes that farmers irrigate to ensure correct leaching fractions. Theoretically all fields in a district will eventually be at the same average root zone EC if they are irrigated with the same on-farm IE's and leaching fractions. In reality, each

field will have a somewhat different IE and leaching fraction due to different crops, soil types, management practices, time of planting, and irrigation methods.

- The restriction of tile drainage until a certain ECdw is reached will also help to balance the salt load because those fields with low salinity will be irrigated with recycled water until maximum salinity is reached.
- The ECdw may be increased by improving on-farm IE (through higher DU's and irrigation scheduling based on crop water requirements) because there will be less deep percolation.
- The costs to a district to move drainage water are minimized when the drainage flows are minimized (neglecting fixed costs). The costs to farmers may not be minimized when on-farm recycling is minimized. The equivalent cost of on-farm recycled water may be much less than a district's or deep well water.
- Control of the blending process of salts and irrigation water (or San Joaquin River assimilative capacity) is maximized when surface runoff and tile drainage are kept separate.
- Response time to available assimilative capacity is minimized with external storage of salts.
- Internal storage of salts (through recycling of tile water) raises many questions (see discussion under Internal Storage of Salts).

TEMPORARY SALT STORAGE

Driving all policy decisions is the amount of salts that a district must dispose of and the assimilative capacity available. If salts have been collected for disposal, and assimilative capacity is not available, then salts must be stored to avoid violating the San Joaquin River water quality standards. Whether a district decides to use internal or external storage will affect many of the previously discussed policy decisions.

External Storage of Salts

Storing salts externally requires a storage facility, called a holding pond. Salts are stored externally in solution. The less concentrated the solution, the larger the holding pond must be. Thus, it is desirable to concentrate salts as much as possible for external storage.

The ability to separate tailwater and tile water becomes extremely important if a district is planning to utilize external storage. It is important for a district to have the ability to measure water quality in individual sumps and at various locations within the district drainage system. If the water in certain parts of the drainage system is of high enough quality, it may be recycled into the irrigation supply to reduce the stored volume of drainage water.

The disadvantages of external storage are the initial capital outlays, maintenance, possible negative environmental impacts, and regulatory requirements (possibly including an EIR or a WDR). The advantages of the external storage of salts are a relatively quick response time when taking advantage of the San Joaquin River's assimilative capacity, absolute knowledge of the minimum amount of district assimilative capacity that may be required, and continual maintenance of both a good district salt balance and a healthy soil root zone.

Internal Storage of Salts

Internal storage means that salts are stored in the soil, thus raising the salinity of the district. This can be accomplished by:

- A district sometimes not accepting tile water, forcing farmers to recycle tile water on-farm or reduce leaching fractions so tile water volume is minimized.

- A district recycling some or all tile water.

Internal storage does not require an external facility, thus no land needs be taken out of production. Additionally, there are no environmental impacts to deal with. There is a limit to the amount of internal storage available. Excessive internal storage is a temporary measure at best since excess salts must eventually be leached out.

There are significant problems regarding the effectiveness of internal storage:

- Salts cannot be removed from the soil quickly when assimilative capacity is available. Soil leaching takes weeks or months, not days or hours.

- Stored salts may start to impact agricultural productivity when no assimilative capacity is available.

- In many cases tile systems are impacted by upslope lateral flows and cannot be shut off without reducing the root zone depth.

- If tile water is being recycled, water of poor quality may have significant negative impacts on crop production if it is applied during critical growth stages such as germination.

- The assimilative capacity of the San Joaquin River may become available, but there may not be enough district irrigation water available to leach salts from the soil. Or, there may not be enough water to go both into a reclamation mode and regular irrigation mode at the same time.

- Commodity prices may rise at the same time the San Joaquin River's assimilative capacity becomes available. In that situation, irrigation water required to leach salts could temporarily become very valuable for crop production, but instead may be needed for leaching.

- There are many times of the year in which farmers cannot leach salts, due to agronomic, soil, or equipment constraints.

CURRENT POLICIES

Each of the districts that are responsible for drainage disposal will now be discussed. The methods by which irrigation water moves into the district and drainage water moves out of the district to the San Joaquin River will be identified. Finally, district policy will be discussed in the framework of the five policy levels, Acceptance, Separation, District Level Recycling, Holding, and Assimilation Water.

BROADVIEW WATER DISTRICT

IRRIGATION WATER DELIVERY

The irrigation water supply for Broadview Water District comes from four sources:

1. A contract with the USBR,
2. One private well (in 1977 and 1991),
3. Subsurface drainage water from twenty-five tile systems within the district, and
4. Unregulated surface drainage from those lands of the Firebaugh Drainage Association lying inside and outside of the district's boundaries.

Referring to **Figure 3**, USBR water is pumped from Station 1, Broadview, on the DMC into BWD's Main Canal. The first lift of the Main Canal is actually a 60 inch reinforced concrete pipeline which discharges into the open channel of the main canal just south of Nees Reservoir. The water flows south in the Main Canal through as many as five more lift stations; Station 2, Station 3, Station 4, Station 5, and Station 6. Pond 5 of the Main Canal begins with a short section of 36 inch and 30 inch diameter pipelines which discharge into the open channel. The last 1/2 mile of the Main Canal after Station 6 in Reach 8 is a 26 inch diameter pipeline.

The farmer owned deep well is located in the southwest corner of Section 14, T13S, R13E. The amount of water pumped from this well is measured but not regulated. Well water is not pumped into the district's laterals.

Water may be turned east out of the Main Canal into one of nine district laterals named 33-1 (turnout), 33-3, Chuck (lateral), 4-1, 4-3, 9-1, 9-3, 16-1, and 16-3 (laterals). Also, water may be delivered west of the Main Canal into the Section 8 lateral. The laterals distribute water by gravity flow to the individual fields except for six turnouts which require pumps. Turnouts are provided at the southwest corners of most quarter-sections within the district.

DRAINAGE DISPOSAL

The FDA includes BWD plus approximately 2230 acres (as of 1991) that are in WWD south and east of BWD. BWD has an agreement with the FDA whereby BWD will allow only surface drainage from the 2230 acres to flow into BWD drains depending on operation to the San Joaquin River. The district either picks up the drainage water at the Nees Pump Station or discharges it to the San Joaquin River in order to meet operational requirements. BWD has informed those farmers in WWD which drain into the FDA that drainage service will be terminated when BWD requires its farmers to recycle.

Currently, the drainage water flowing from the 2230 acres of FDA consists only of tailwater. No tile water is allowed into BWD.

BWD has a system of open drains which convey mixed tailwater and tile water. Many of BWD's fields have farmer owned tile drain systems. The majority of tile drain installation occurred between 1965 and 1980. Tile water is collected at various sumps and pumped into the open drains. The sumps and pumps are also owned and maintained by BWD farmers. BWD supplies and reads the water meters on the pumps. BWD has no means of separating tailwater and tile water.

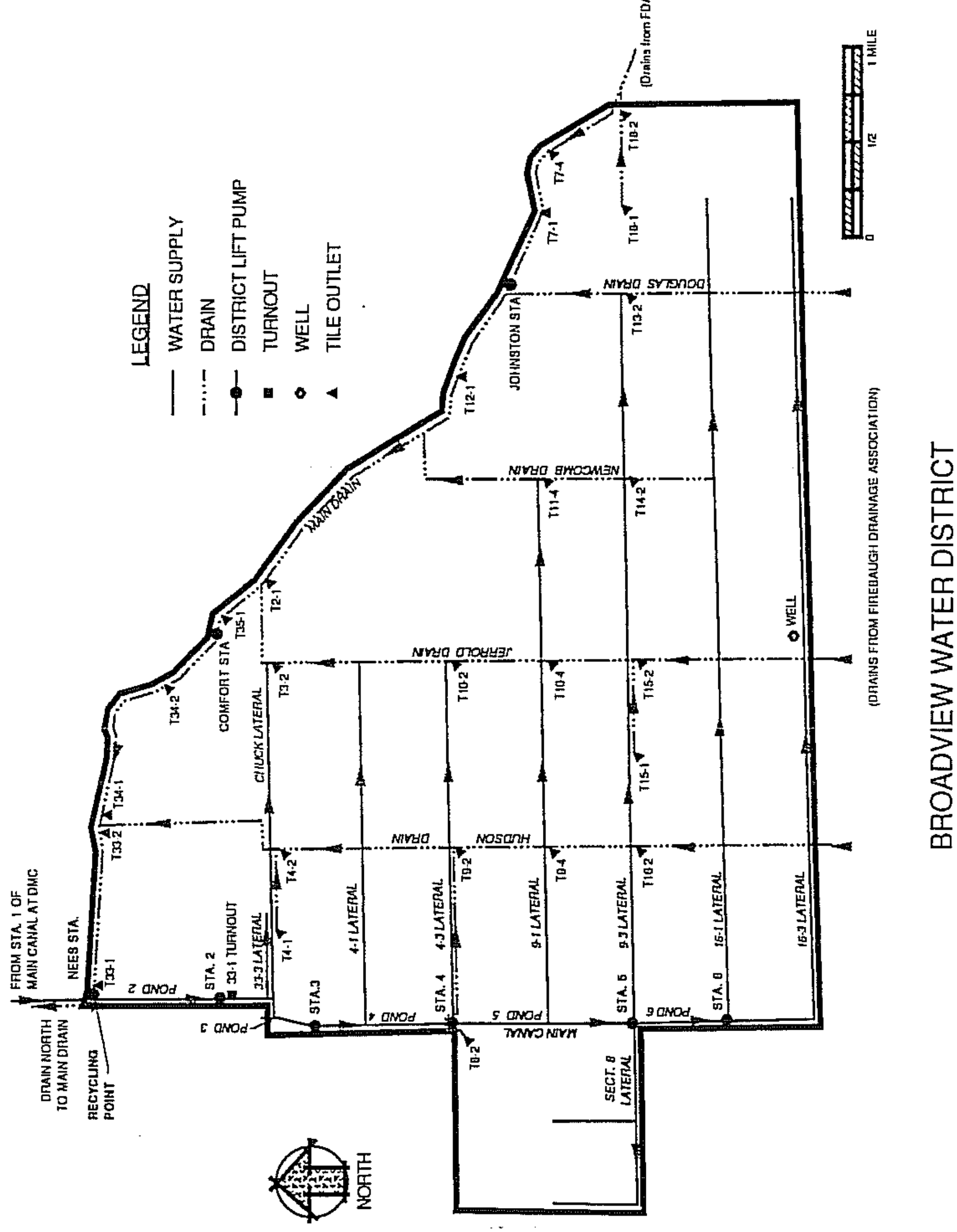

BROADVIEW WATER DISTRICT
LEGEND
WATER SUPPLY
DRAIN
DISTRICT LIFT PUMP
TURNOUT
WELL
TILE OUTLET
NORTH
1 MILE
MAIN DRAIN
MAIN CANAL
JOHNSTON STA
COMFORT STA
NEES STA.
STA. 2
STA.3
STA. 4
STA. 5
STA. 6
DOUGLAS DRAIN
NEWCOMB DRAIN
JERROLD DRAIN
HUDSON DRAIN
CHUCK LATERAL
33-3 LATERAL
4-1 LATERAL
4-3 LATERAL
9-1 LATERAL
9-3 LATERAL
16-1 LATERAL
16-3 LATERAL
SECT. 8 LATERAL
POND 2
POND 3
POND 4
POND 5
POND 6
33-1 TURNOUT
WELL
(DRAINS FROM FIREBAUGH DRAINAGE ASSOCIATION)
(Drains from FDA)
FROM STA. 1 OF MAIN CANAL AT DMC
DRAIN NORTH TO MAIN DRAIN
RECYCLING POINT

Figure 3

The drainage water flows, by gravity, in a northerly direction toward the drain that runs the length of BWD's northern boundary. The drain (labeled FDA Drain) flows northwesterly until it terminates at the Main Canal at the Nees Pump Station. At this point, drainage water is either recycled through the Nees Pump Station into the Main Canal or discharged through the Drain Outlet pipeline to the San Joaquin River. There are two pump stations in the perimeter drain; Comfort and the Johnston.

The BWD Drain Outlet north of the Nees Pump Station is a pipeline which terminates into a drain owned by FCWD about 3/8 mile north of the DMC. The pipeline size restricts the flowrate from BWD to a maximum of 25 cfs, but at the DMC the size of the outlet pipe increases to a 35 cfs capacity so the district can add up to 10 cfs of water for dilution.

Referring to **Figure 3**, it is seen that the Broadview Drain goes through the measuring point BV-3, over the DMC, discharges into a FCWD drain and unites with FCWD spill water. The drain then flows west and connects with the Crooked Drain (which also carries drainage from FCWD), flows northwest to a siphon under CCID's Outside Canal and intersects with the Main Drain which parallels CCID's Main Canal.

The drainage water in the Main Drain may flow through the southern portion of GWD in the Agatha or Camp 13 Canals, depending on GWD operations. (Refer to the section "Grassland Water District Drainage Operations" for a description of how agricultural drainage is conveyed through GWD). BWD drainage water eventually enters the San Joaquin River through either Salt Slough or Mud Slough (North).

DISTRICT DRAINAGE POLICY

SUMMARY

BWD's drainage policy (**Figure 4**) can be summarized according to the five policy levels as follows:

- **Acceptance-** BWD will accept either tile water or tailwater from within BWD.
- **Separation-** BWD does not separate the tailwater and tile water.
- **District Level Recycling-** BWD will recycle drainage at a district level to meet peak irrigation water demands and discharge limitations (quality, quantity, etc.)

BROADVIEW WATER DISTRICT

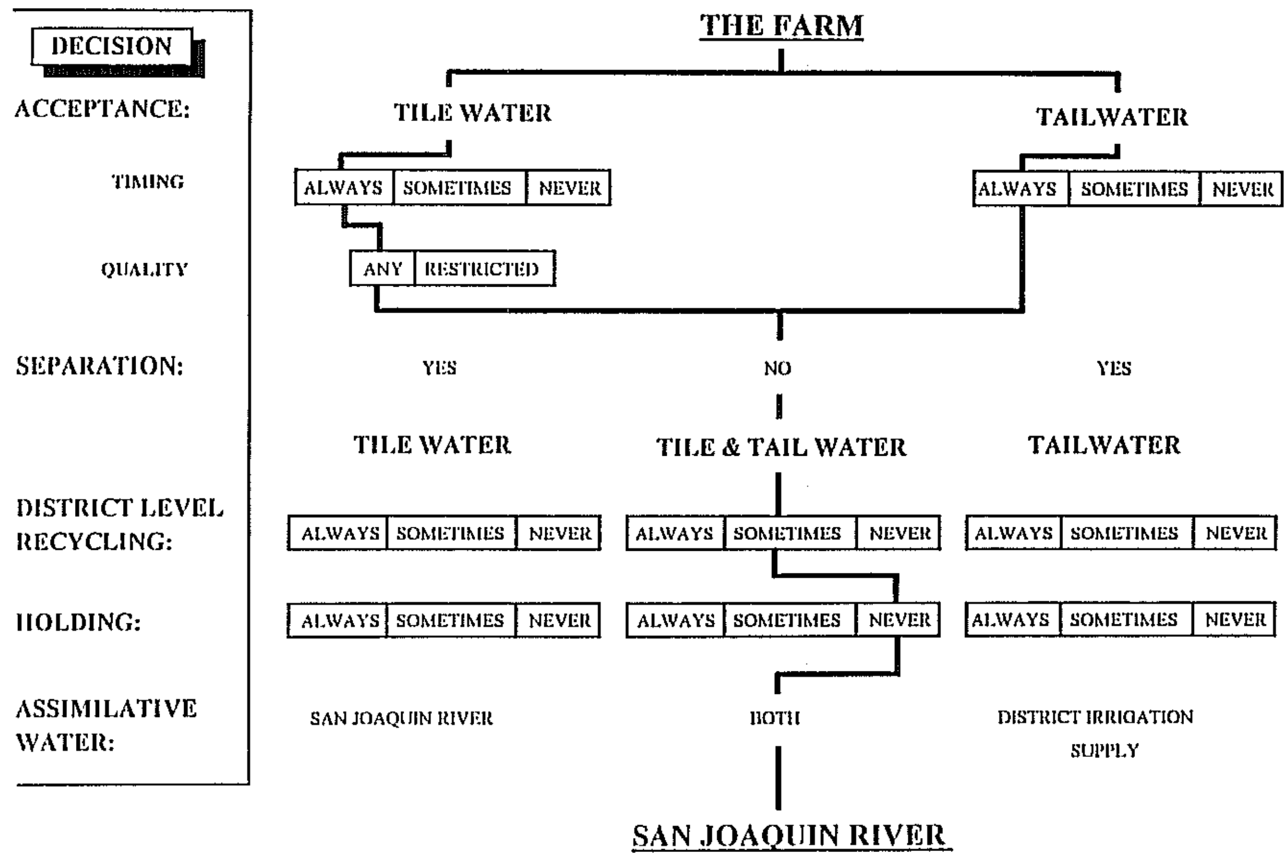


Figure 4

- **Holding-** BWD does not have an external storage facility except the drainage system itself.

- **Assimilation Water-** BWD has no formal policy regarding the use of the assimilative capacity of the San Joaquin River or the district. BWD has the ability to dilute the drainage discharges with DMC water. This has been done in the past to help BWD meet water quality requirements when GWD used rain water for irrigation. In 1991, some water was used for dilution from another source.

ACCEPTANCE

BWD will accept both tile water of any quality and tailwater from land within BWD. BWD does not accept tile water from the 2230 acres of the FDA outside of BWD. There are approximately 1280 acres (of the district's approx. 9,000 irrigable acres) in the southeastern portion of the district that are serviced by farmer owned tailwater return systems. At present, on-farm tailwater reuse is encouraged. BWD management feel that if all farmers recycled their tailwater on-farm there would be little, if any, need for recycling of drainage water to supplement the current pumping capacity on the DMC. Because BWD is concerned about its drainage problem, the use of any on-farm recycled drainage water or on-farm well water for irrigation is metered. The well water and recycled water are not charged for by the district, but the volumes are included in the calculation of the total volume of irrigation water applied to a field, and thus affect the tiered price of delivered water.

BWD has plans to install a 160 cfs outlet on the San Luis Canal that would supply water to the district via gravity flow. If this outlet becomes operational, BWD policy will be to require all farmers to recycle all tailwater on-farm. This project is currently on hold due to the threat of legal action by the NRDC if the USBR renews the BWD water service contract without a full EIS.

SEPARATION

BWD does not separate tile water and tailwater. However, when (and if) the new outlet on the San Luis Canal is operational it will be BWD policy to accept only tile water, thus in effect separating tile water and tailwater.

DISTRICT LEVEL RECYCLING

Most recycling of drainage water is done at a district level rather than on-farm. As previously noted, tailwater and tile water eventually flow into the Main Drain. This drain terminates at the

Main Canal at the Nees Pump Station. At this point, drain water can be pumped into the Main Canal for recycling on BWD land or discharged in the Broadview Drain Outlet Pipe.

There are three sets of criteria that govern the amount of recycling in BWD:

1. BWD's contract with GWD allows BWD drainage water to flow through GWD conveyance channels. BWD began draining through GWD channels in January 1983. Under the agreement between BWD and GWD, BWD can discharge up to 35 cfs through GWD. The water must be less than 2,500 ppm TDS and contain less than 6 ppm of Boron.

   BWD's drainage pipeline (the Drain Outlet pipeline north of Nees Pump Station) restricts drain flows from BWD to a maximum of 25 cfs. BWD can add up to 10 cfs from its DMC supply if needed to meet the contract water quality requirements.

   The original intent of the BWD/GWD agreement was to provide BWD with an outlet for its drainage, and thus the ability to maintain a salt balance, and also to provide an additional water supply to GWD, which was and is chronically short of water.

   GWD (which consists primarily of waterfowl habitat) has not used BWD drain water since 1985, although they continue to convey drainage water, on its way to the San Joaquin River, in their supply channels . Thus, the water quality standards in the BWD/GWD contract currently do not have an effect on the amount of recycling by BWD since GWD does not use BWD drainage water. BWD has shut off drainage through GWD during fall flood periods so as to not impact GWD water quality.

2. Agronomic considerations for BWD crops in terms of both water supply and water quality govern recycling. BWD has a water supply contract with the USBR for 27,000 acre-feet/year delivered from the DMC. However, pumping capacity at their main outlet on the DMC of 125 cfs is sometimes less than total grower demand in the district. In these situations BWD uses some of its drainage water to augment the DMC water.

   Peak irrigation water requirements occur during two periods of the year; the pre-plant irrigation season which occurs from December through January, and the hottest parts of summer through July and August. However, many of BWD's farmers are switching to sprinkler systems for pre-plant irrigation, which may alleviate some of the capacity problems during that time. It is expected that in the future, recycling to handle peak delivery requirements will only occur in summer months.

In the 1991 crop year, BWD opened its drainage outlet a total of 208 days. Thirty of the days on which the outlet was closed took place between November 15, 1990 and February 16, 1991; the pre-plant irrigation season. The drain was closed for another 84 days from June 5, 1991 through August 27, 1991; the peak summer water use period.

The average TDS of BWD irrigation water before and after drainage recycling is shown in **Table 2**. Due to the experience of having no drainage outlet before 1983, BWD growers are acutely aware of the effects of salinity. For the long term, BWD seeks to remain a net salt exporter, which was the case until 1991.

When recycling, short term considerations include potential germination problems and the desire to grow salt sensitive crops, such as processing tomatoes and melons. **Table 2** shows the average salinity in BWD irrigation water has remained below about 800 ppm TDS since the drainage outlet became available in 1983. BWD seeks to keep short term peaks in salinity below 1000 ppm TDS for 1991 and 1992, and preferably below 800 ppm TDS.

3. Water quality standards are set by the CVRWQCB for the San Joaquin River. It is not clear how BWD will coordinate its drainage operations with other drainers to meet these water quality standards.

Table 2
Salinity of Delivered Water
Broadview Water District

Year	**Average Salinity of Delivered Water ECw, dS/m**
1981	3.21
1982	2.89
1983	0.89
1984	0.74
1985	0.65
1986	0.67
1987	0.56
1988	0.87
1989	0.75
1990	1.06
1991	1.25
1992	1.00

Note: Previous to 1983, BWD did not have an outlet and was recycling all tile and tail water.

HOLDING

BWD does not have an external holding facility. If drainage is not recycled it flows directly to the San Joaquin River.

ASSIMILATION WATER

BWD does not have a formal policy for the use of the assimilative capacity of the San Joaquin River or the district. Recent DOP's submitted by BWD to the CVRWQCB have not indicated what their final policy will be. The drainage and irrigation water supplies of the BWD are shown in **Table 3.**

Table 3
Drainage and Irrigation Water Supply
Broadview Water District

Year	Delivered Water (AF)	Irrigated Acreage (Ac)	Tile Drainage Total (AF)	Drainage Out of District (AF)
1981	28,932	9,025		
1982	25,211	8,828		
1983	15,690	5,510		
1984	31,911	8,960		
1985	28,240	8,665		
1986	24,628	8,169	4,626	
1987	23,308	7,870	3,704	
1988	25,891	8,736	3,628	
1989	25,200	8,686	3,735	
1990	20,582	8,160	3,464	
1991	12,902	5,539	1,808	
1992	9,086	4,483	853	

Note: Drainage data is combined with CCID and FCWD. See section under FCWD.

CENTRAL CALIFORNIA IRRIGATION DISTRICT

CAMP 13 STUDY AREA

IRRIGATION WATER DELIVERY

The Central California Irrigation District (CCID) is party to an agreement between the USBR and several holders of pre-1914 riparian water rights on the San Joaquin River. The agreement, negotiated in the late 1930s, is referred to as the Exchange Contract. The water districts that are party to the agreement are referred to as the Exchange Contractors.

In summary, the Exchange Contract provided the USBR with the water rights necessary to build the Friant Dam, the Friant-Kern Canal, and the Madera Canal. The USBR was then able to deliver San Joaquin River water to lands along the western slope of the Sierra Nevada mountain range. In return for the water rights, the USBR agreed to deliver water from the Sacramento River, stored at Shasta Dam, to the Exchange Contractors through the DMC.

The DMC begins at the Tracy Pumping Plant on the southern edge of the Sacramento/San Joaquin Delta and flows southerly to the Mendota Pool near the town of Mendota. CCID's two main canals, the Main and the Outside, begin at the Mendota Pool and flow northwesterly towards the town of Los Banos where the canals turn north. Both CCID canals end north of the town of Gustine. Although there are some turnouts delivering water directly from the DMC to fields in CCID, the majority of CCID's DMC water is delivered through the Mendota Pool into the two main CCID canals.

The Exchange Contract includes restrictions on maximum monthly flowrate and volume. CCID also has over 40 district owned wells to supplement their DMC water during peak water use months. There is also an undetermined number of privately owned wells in the district.

DRAINAGE DISPOSAL

There are several drainage districts within CCID boundaries disposing of both tile water and tailwater. One area within CCID, which is not in a separate drainage district, discharges significant quantities of selenium with its tile water. This area is referred to as the Camp 13 and is the focus of this discussion.

The approximately 6,000 acres of the Camp 13 lie between the Main and Outside Canals and extends from the City of Firebaugh to about one mile east of Brannon Avenue as shown in **Figure 5**. The fields within Camp 13 are supplied water by gravity flow from turnouts on the Outside Canal. There are no active private or district owned wells within Camp 13.

Tile water is collected in eleven sumps throughout Camp 13. Nine of these sumps pump into the Main Drain which parallels the Main Canal. The Main Drain also carries tailwater from farms in Camp 13 and drainage water from PWD, FCWD, and BWD/FDA. The drainage water eventually flows into the GWD through either the Agatha or Camp 13 Canals. (Refer to the section "Grassland Water District Drainage Operations" for a discussion of how agricultural drainage is moved through GWD). Drainage water from Camp 13 eventually enters the San Joaquin River through either Salt Slough or Mud Slough (North).

The tile systems, sumps, and pumps within Camp 13 are owned and maintained by farmers. CCID installed hour meters on the sump pumps. The hours of operation, along with PG&E records, and estimates of pump lift and efficiency, are the bases for estimates of CCID tile water from Camp 13.

DISTRICT DRAINAGE POLICY

SUMMARY

CCID's drainage policy (**Figure 6**) can be summarized according to the five policy levels as follows:

- **Acceptance-** CCID will accept either tile water or tailwater.
- **Separation-** CCID does not separate the tailwater and tile water.
- **District Level Recycling-** One sump in Camp 13 is recycling tile water back into the Outside Canal. All others are not recycled. (This is true for other parts of CCID also.)
- **Holding-** CCID does not have an external holding facility except the drainage system itself.
- **Assimilation Water-** CCID has no formal policy regarding the use of the assimilative capacity of the San Joaquin River or the district. An appendix to CCID's 1992 DOP indicated that using district assimilative capacity would be no problem.

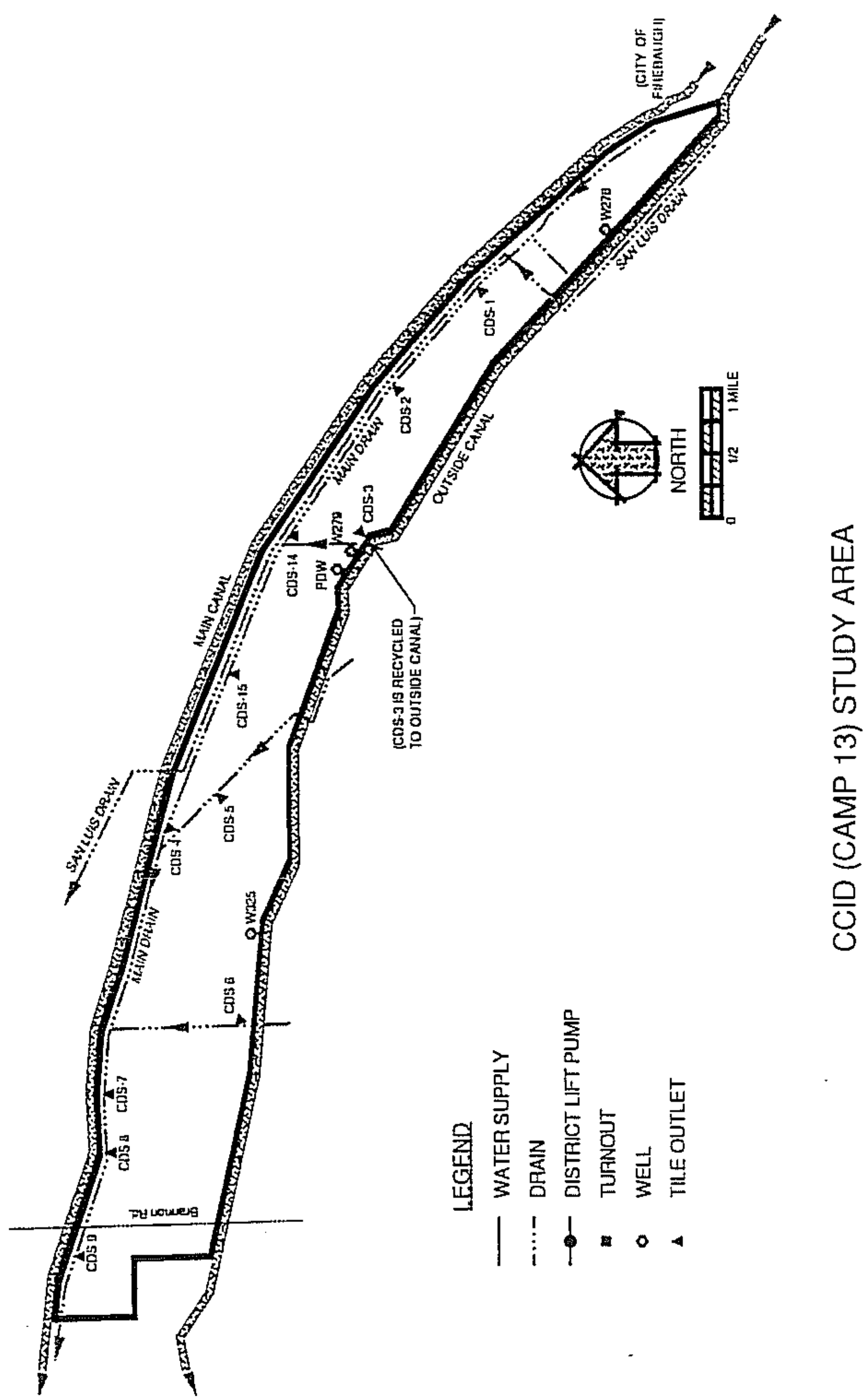

CCID (CAMP 13) STUDY AREA
LEGEND
WATER SUPPLY
DRAIN
DISTRICT LIFT PUMP
TURNOUT
WELL
TILE OUTLET
NORTH
0
1/2
1 MILE
MAIN CANAL
MAIN DRAIN
OUTSIDE CANAL
SAN LUIS DRAIN
(CITY OF FIREBAUGH)
(CDS-3 IS RECYCLED TO OUTSIDE CANAL)
Brannon Rd.
CDS-1
CDS-2
CDS-3
CDS 4
CDS-5
CDS 6
CDS-7
CDS 8
CDS 9
CDS-14
CDS-15
W278
W279
W325
POW

Figure 5

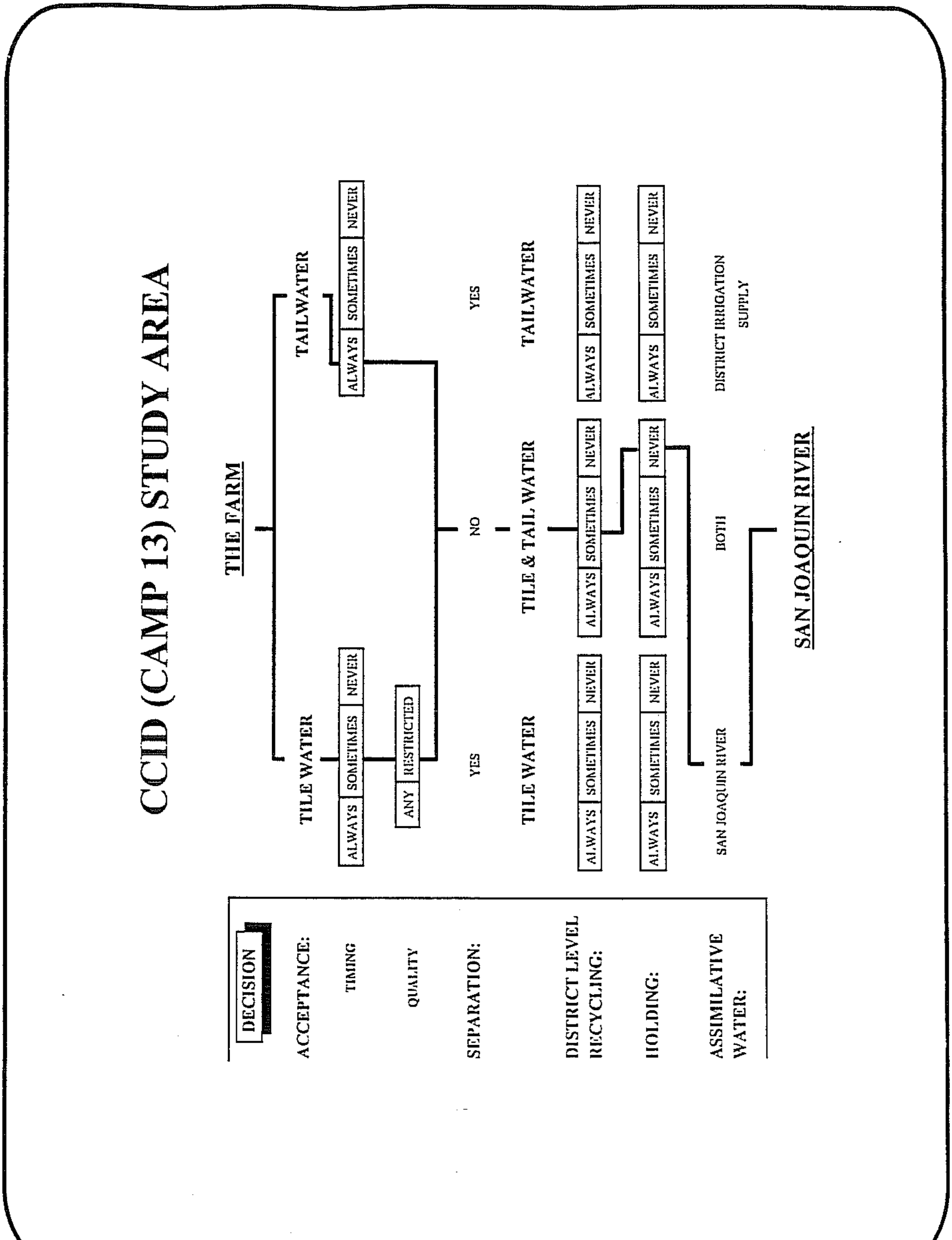

CCID (CAMP 13) STUDY AREA
TILE FARM
DECISION
ACCEPTANCE:
TIMING
QUALITY
SEPARATION:
DISTRICT LEVEL RECYCLING:
HOLDING:
ASSIMILATIVE WATER:
TILE WATER
ALWAYS
SOMETIMES
NEVER
ANY
RESTRICTED
TAILWATER
ALWAYS
SOMETIMES
NEVER
YES
NO
YES
TILE WATER
ALWAYS
SOMETIMES
NEVER
ALWAYS
SOMETIMES
NEVER
TILE & TAIL WATER
ALWAYS
SOMETIMES
NEVER
ALWAYS
SOMETIMES
NEVER
TAILWATER
ALWAYS
SOMETIMES
NEVER
ALWAYS
SOMETIMES
NEVER
SAN JOAQUIN RIVER
BOTH
DISTRICT IRRIGATION SUPPLY
SAN JOAQUIN RIVER

Figure 6

ACCEPTANCE

CCID will accept tile water or tailwater into its drainage system.

SEPARATION

CCID does not separate tile water and tailwater.

DISTRICT LEVEL RECYCLING

Certain sumps and drains within CCID pump back into the delivery system at various points within the entire service area of CCID. There is no formal policy regarding this recycling.

Currently there is one sump in Camp 13 which recycles tile water by pumping drainage water directly back into the Outside Canal. There are no records for how much drainage water is recycled in this manner. CCID currently does not recycle any tailwater or tile water collected by the other nine active sumps in Camp 13.

In its 1991 DOP, CCID stated that it was attempting to work with farmers in the district to construct facilities to take all drainage from Camp 13 back into CCID supply canals.

HOLDING

CCID does not have an external holding facility.

ASSIMILATION WATER

CCID does not have a formal policy regarding the assimilative capacity required to blend drainage water in Camp 13. In its 1992 DOP, CCID indicated that taking the drainage water back into the Main Canal would cause no significant degradation to the irrigation supply water quality. The DOP indicated a maximum expected tile water flow of 2 cfs. Using average water qualities, CCID estimated that blending 2 cfs of tile water with 16 cfs of irrigation supply water would dilute the drainage water sufficiently to meet the water quality standards of the San Joaquin River. CCID's Main Canal handles at least 1200 cfs during most of the irrigation season in the reach next to Camp 13. It could be expected that farmers immediately downstream from any planned discharge of drainage water into the Main Canal would receive irrigation water degraded to some degree, depending on the speed and effectiveness of blending. The drainage and irrigation water supplies of the CCID are shown in **Table 4**.

Table 4
Drainage and Irrigation Water
CCID Camp 13 Study Area

Year	Delivered Water (AF)	Irrigated Acreage (Ac)	Tile Drainage Total (AF)	Drainage Out of District (AF)
1981	15,251	3,183		
1982	15,251	3,183		
1983	15,251	3,183		
1984	15,251	3,183		
1985	18,914	5,411		
1986	15,072	4,540		
1987	16,255	5,072		
1988	16,738	5,219		
1989	11,049	4,066		
1990	13,081	4,436		
1991	16,351	4,555		
1992	14,546	4,900		

Note: Drainage Out of District data is combined with BWD and FCWD. See section under FCWD. There is no data available for the tile drainage data in CCID Camp 13 area.

CHARLESTON DRAINAGE DISTRICT

IRRIGATION WATER DELIVERY

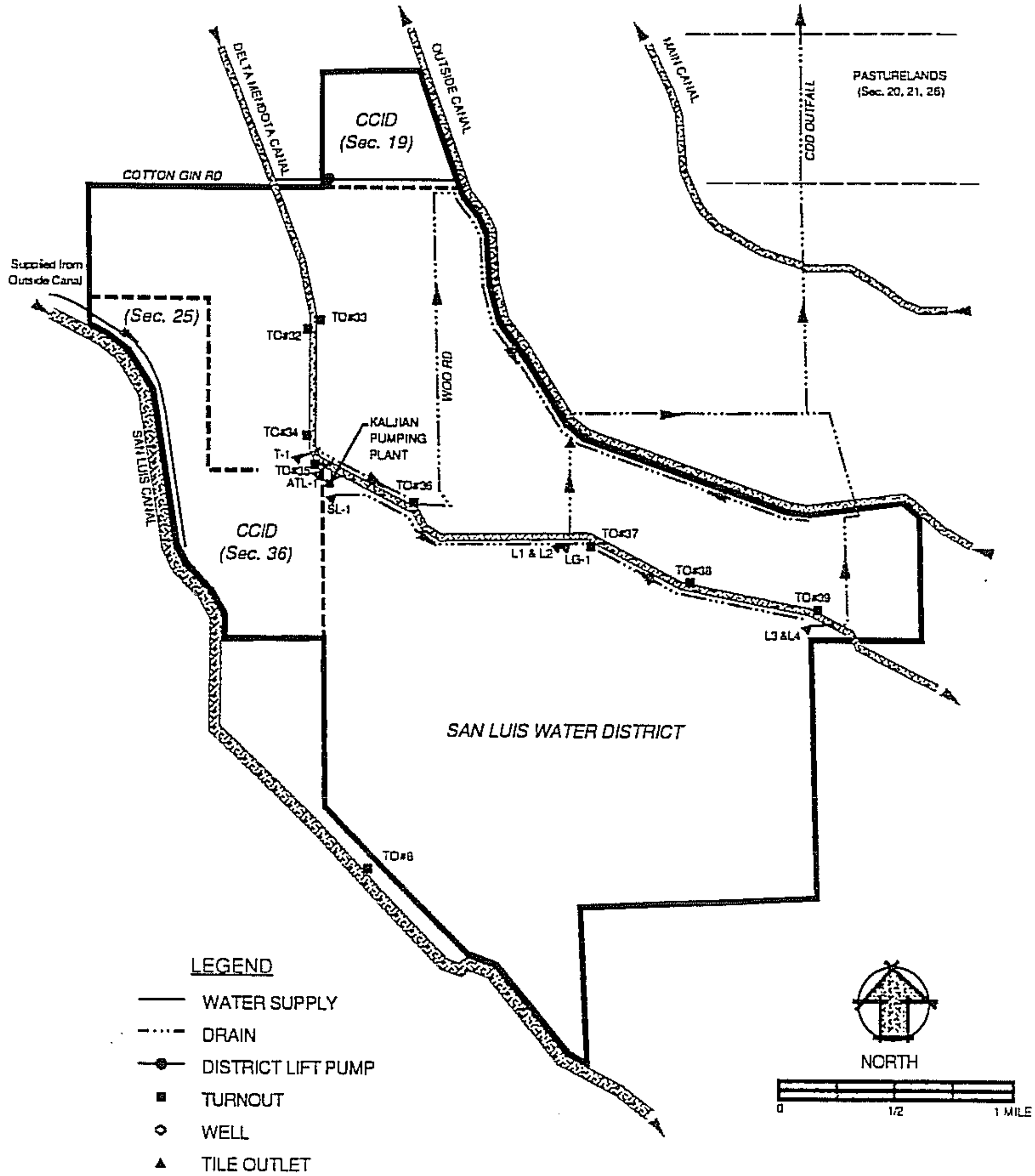
Fields within Charleston Drainage District are supplied with water from both the SLWD and CCID. Referring to **Figure 7**, CCID water is delivered from a turnout on the DMC to 160 acres in the southwest quarter of Section 19, T11S, R11E. CCID water, originally delivered from the Outside Canal to a large farm in CCID, but outside of CDD, flows into CDD through a farmer owned system to fields in Sections 25 and 36 of T11S, R10E. All other irrigation water is SLWD water delivered from four turnouts on the upslope side (westerly) and four turnouts on the downslope side (easterly) of the DMC. There are no deep wells in CDD.

DRAINAGE DISPOSAL

Approximately 3,600 acres of CDD's 4,275 acres have subsurface tile drain systems installed, all of which are farmer owned and maintained. The tile water from drain systems on the upslope side of the DMC is collected at sumps and pumped across the DMC. Tile water from drain systems on the downslope side of the DMC flows by gravity to the perimeter drain where it mixes with tailwater and the drainage water from the upslope side.

Tile water may be kept separate from tailwater on the upslope side of the DMC. Tailwater is recirculated through farmer owned systems on both sides of the DMC. Connections are in place to allow the recirculation of tile water from fields on both sides of the DMC. It is unknown how much tile water or tailwater is currently recycled.

Tile water is collected in six sumps on the upslope side of the DMC designated as T-1, ALT-1, SL-1, L-1/L-2, LG-1, and L-3/L-4. It can be kept separate from tailwater until pumped across the DMC.



CHARLESTON DRAINAGE DISTRICT

Figure 7

Drainage water from T-1 and ALT-1 is pumped across the DMC near the Kaljian Pumping Plant to an open drain on the downslope side of the DMC. The drainage water flows southerly to Woo Road, turns north, intercepts Cotton Gin Road, where it then turns southeasterly along CCID's Outside Canal. It flows by gravity across the Outside Canal near the intersection of Sections 29, 30, 31, and 32 of T11S, R11E, then north to the main CDD outfall drain. The outfall drain flows north again, through measuring point CH-1 into GWD's Gadwall Canal. (Refer to the section "Grassland Water District Drainage Operations" for a description of how agricultural drainage is conveyed through GWD). CDD drainage water eventually enters the San Joaquin River through either Salt Slough or Mud Slough (North).

Drainage water from SL-1, L-1/L-2, and LG-1 is pumped north across the DMC at LG-1 to an open drain that intercepts the previously mentioned drain that runs along CCID's Outside Canal.

Drainage from L-3/L-4 is pumped across the DMC northward to a gravity siphon that crosses the Outside Canal and then meets the main CDD outfall.

Tile water from CDD lands, on the downslope side of the DMC, is collected and flows by gravity to the drain paralleling CCID's Outside Canal and then through the CDD outfall.

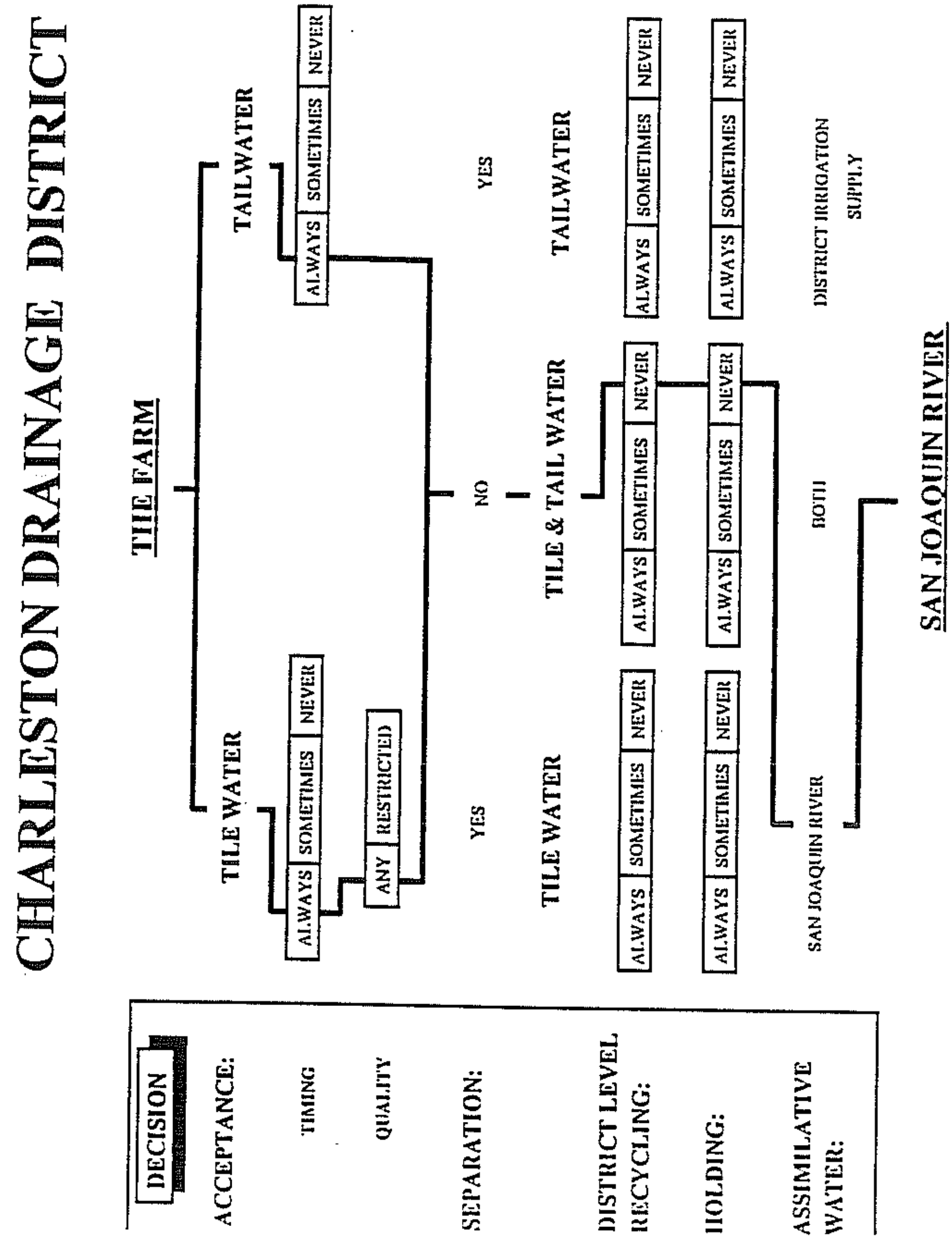
The CDD outfall is continually open. There are no means available, except for voluntary recycling by CDD farmers, for restricting CDD drainage to the San Joaquin River.

DISTRICT DRAINAGE POLICY

SUMMARY

CDD's drainage policy (**Figure 8**) can be summarized as follows:

- **Acceptance-** CDD will accept either tile water or tailwater.
- **Separation-** CDD keeps some tile water separate from tailwater on the upslope side of the DMC. However, as soon as it is pumped to the downslope side, it is mixed with tailwater.
- **District Level Recycling-** CDD does not recycle drainage water at a district level.
- **Holding-** CDD does not have an external holding facility except the drainage system itself.



CHARLESTON DRAINAGE DISTRICT
THE FARM
TILE WATER
TAILWATER
ALWAYS
SOMETIMES
NEVER
ANY
RESTRICTED
YES
NO
YES
TILE WATER
TILE & TAIL WATER
TAILWATER
SAN JOAQUIN RIVER
BOTH
DISTRICT IRRIGATION SUPPLY
SAN JOAQUIN RIVER
DECISION
ACCEPTANCE:
TIMING
QUALITY
SEPARATION:
DISTRICT LEVEL RECYCLING:
HOLDING:
ASSIMILATIVE WATER:

Figure 8

- **Assimilation Water-** CDD has no formal policy regarding the use of the assimilative capacity of the San Joaquin River or the district. In its 1992 DOP, CDD indicated that it plans to utilize the maximum assimilative capacity of the San Joaquin River.

ACCEPTANCE

CDD will accept either tile water or tailwater.

SEPARATION

There is no formal policy regarding separation of tile water and tailwater. The two can be kept separate on the upslope side of the DMC.

DISTRICT LEVEL RECYCLING

There is significant reuse of tailwater, and possibly tile water, through farmer owned systems. A large, farmer owned tailwater return system was installed in 1991 near sumps L-1/L-2 on the upslope side of the DMC. This system can return tailwater to the western most CDD boundary near TO #8 on the San Luis Canal. Another reuse pump was installed on the eastern perimeter drain and recirculates a mix of tile water and tailwater. No district records are kept of how much drainage water is recycled within CDD.

Also, some CDD drainage water flowing in the main outfall is picked up for use on pasture lands east and west of the outfall drain, outside of CDD boundaries, in Sections 20, 21, and 26, T11S, R11E. However, drainage water from this land also returns to the CDD outfall. This use is upstream of CDD's CH-1 measuring point.

There is no recycling of collected tile water at a district level by CDD within CDD boundaries.

HOLDING

CDD does not have a holding facility.

ASSIMILATION WATER

CDD's 1992 DOP indicated it will attempt to utilize the San Joaquin River's assimilitive capacity when available. There is no indication of the district's operational plans when assimilitive capacity is not available. The drainage and irrigation water supplies of the CDD are shown in **Table 5.**

Table 5
Drainage and Water Supply
Charleston Drainage District

Year	Delivered Water (AF)	Irrigated Acreage (Ac)	Tile Drainage Total (AF)	Drainage Out of District (AF)
1981	14,030	3,618		
1982	11,973	3,643		
1983	11,591	3,612		
1984	13,691	3,477		
1985	12,119	3,232		3,090
1986	10,264	2,897		3,186
1987	13,891	3,724		4,769
1988	14,428	3,582		6,136
1989	12,263	3,602	130	2,799
1990	11,127	3,494	2,425	2,126
1991	10,218	3,890		781
1992	9,630	3,890	319	781

FIREBAUGH CANAL WATER DISTRICT

IRRIGATION WATER DELIVERY

Firebaugh Canal Water District is party to an agreement between the USBR and several holders of pre-1914 riparian water rights on the San Joaquin River. The agreement, negotiated in the late 1930s, is referred to as the Exchange Contract. The water districts that are party to the agreement are referred to as the Exchange Contractors.

In summary, the Exchange Contract provided the USBR with the water rights necessary to build the Friant Dam, the Friant-Kern Canal, and the Madera Canal. The USBR was then able to deliver San Joaquin River water to lands along the western slope of the Sierra Nevada mountain range. In return for the water rights, the USBR agreed to deliver water from the Sacramento River, stored at Shasta Dam, to the Exchange Contractors through the DMC.

The DMC starts at the Tracy pumping plant on the southern edge of the Sacramento/San Joaquin Delta and flows southerly to end at the Mendota Pool near the town of Mendota. The Mendota

Pool has traditionally been used by FCWD, CCID, and CCC as their turnout point on the San Joaquin River.

Referring to **Figure 9**, FCWD draws water from the Mendota Pool and pumps it up into the Intake Canal. The Intake Canal flows west to supply the First, Second, and Third Lift Canals. These three canals then flow roughly parallel northwesterly along the prevailing ground contour to distribute irrigation water throughout the district. Water is delivered via gravity turnouts to the individual fields.

There are ten district owned deep wells. However, the groundwater in the district is of very poor quality. The wells are not used except in times of very low surface water supplies. There are no farmer owned deep wells in the district.

DRAINAGE DISPOSAL

Approximately half of the 21,700 irrigable acres are served by farmer owned subsurface drainage systems, which include collector sumps and pumps. FCWD maintains a series of open drains and recycling lift pumps to dispose of both tile water and tailwater.

As discussed below, tile water from twelve subsurface collector sumps is recycled back into FCWD supply canals. There are several other flow paths for the remaining drainage water. Some drainage water flows to the Delta/Mendota Wasteway. Some drainage water is recycled back into CCID's Outside Canal. A large portion goes through GWD on its way to the San Joaquin River. Drainage water directed through GWD goes through measuring points FC-1, FC-2, or FC-3. All drainage water ends up in the Main Drain paralleling CCID's Main Canal. From there the drainage water goes through GWD's Agatha or Camp 13 Canals. (Refer to the section "Grassland Water District Drainage Operations" for a discussion of how agricultural drainage is moved through GWD). FCWD drainage water that is not recycled in FCWD or CCID canals eventually enters the San Joaquin River through either the Delta/Mendota Canal Wasteway, Salt Slough or Mud Slough (North).

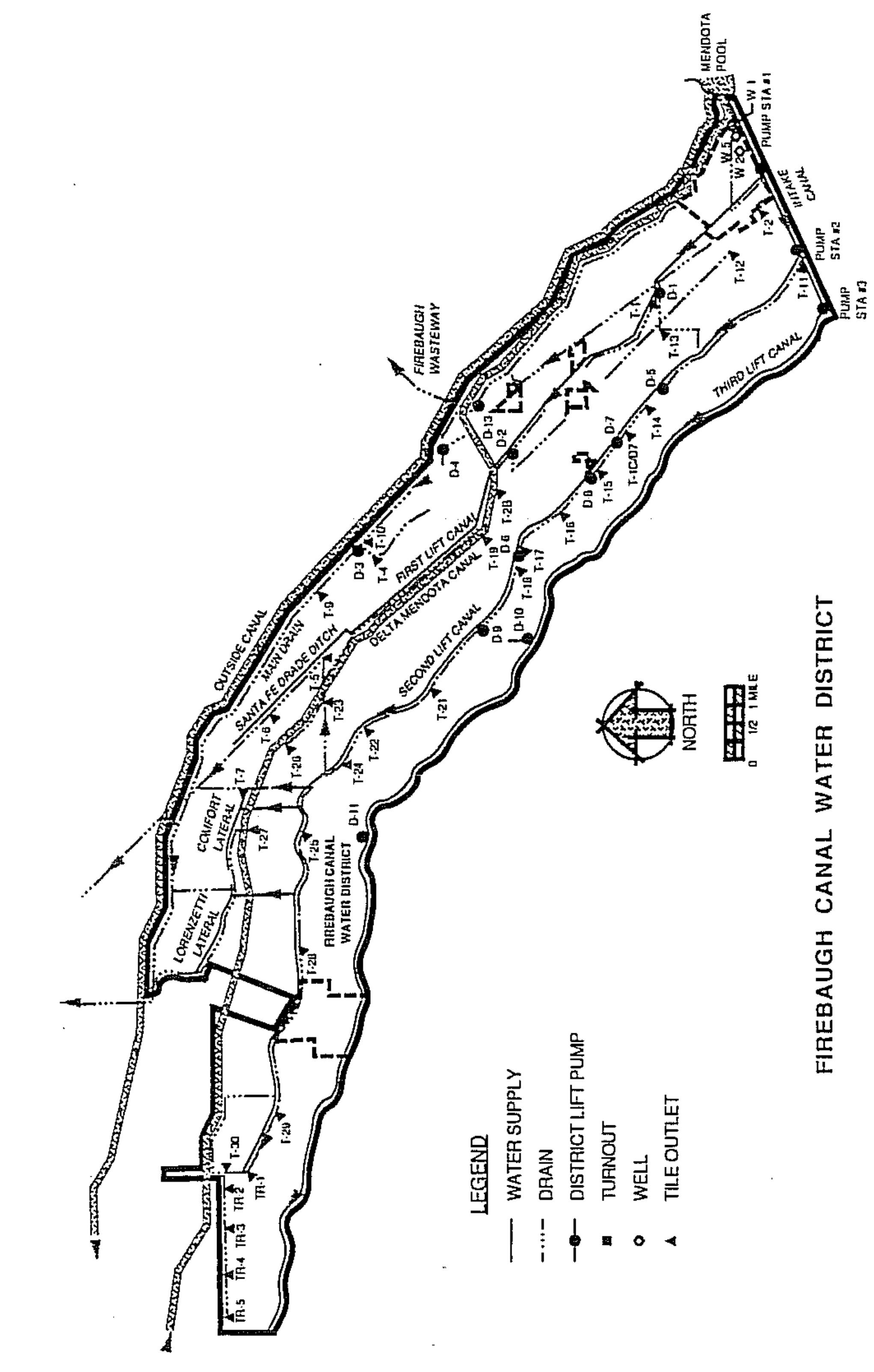

MENDOTA POOL
PUMP STA #1
INTAKE CANAL
PUMP STA #2
PUMP STA #3
THIRD LIFT CANAL
FIREBAUGH WASTEWAY
OUTSIDE CANAL
MAIN DRAIN
SANTA FE GRADE DITCH
FIRST LIFT CANAL
DELTA MENDOTA CANAL
SECOND LIFT CANAL
COMFORT LATERAL
LORENZETTI LATERAL
FIREBAUGH CANAL WATER DISTRICT
NORTH
0 1/2 1 MILE
LEGEND
WATER SUPPLY
DRAIN
DISTRICT LIFT PUMP
TURNOUT
WELL
TILE OUTLET
FIREBAUGH CANAL WATER DISTRICT

Figure 9

DISTRICT DRAINAGE POLICY

SUMMARY

FCWD's drainage policy (**Figure 10**) can be summarized according to the five policy levels as follows:

- **Acceptance-** FCWD will accept either tile water or tailwater.
- **Separation-** FCWD does not separate tailwater and tile water.
- **District Level Recycling-** FCWD will recycle all drainage water in certain drains at several points within the district, mostly south of Nees Avenue.
- **Holding-** FCWD does not have an external holding facility except the drainage system itself.
- **Assimilation Water-** FCWD has no formal policy regarding the use of the assimilative capacity of the San Joaquin River or the district. It has not been noted that FCWD has used its irrigation water supply to dilute drainage.

ACCEPTANCE

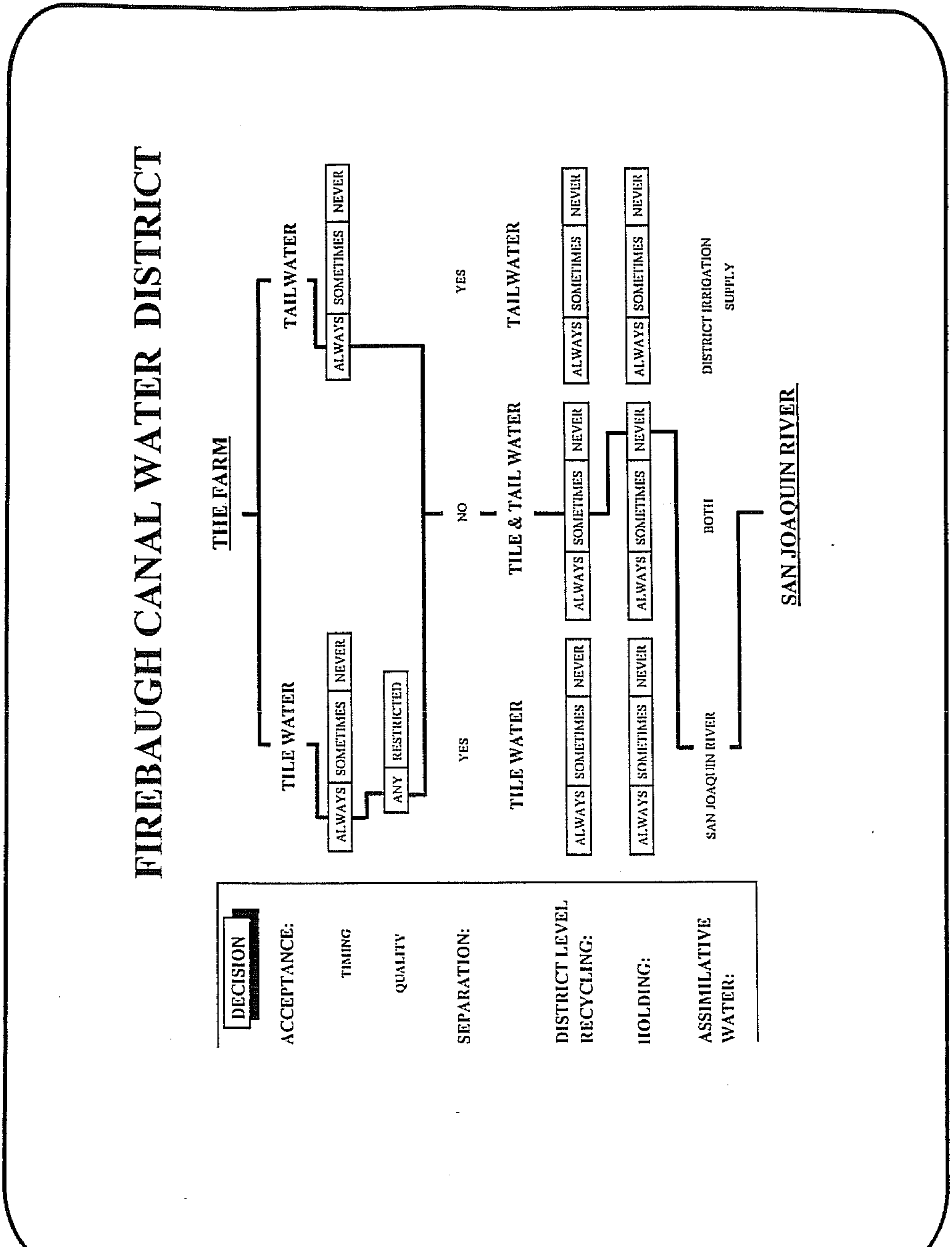
FCWD will accept both tailwater and tile water. FCWD's policy is to encourage on-farm recycling of tailwater.

SEPARATION

FCWD does not separate tile water and tailwater.

DISTRICT LEVEL RECYCLING

According to FCWD's 1992 DOP, tile water is being recycled from 12 sumps. The sumps being recycled are named T-1, T-2, T-4, T-9, T-11, T-12, T-13, T-14, T-15, T-16, T-17, and T-18. These sumps lie in the southern part of FCWD. The sumps collecting the tile water pump to open drains. There are low lift pumps in the open drains that then recycle both the tile water and tailwater back into FCWD supply canals.


FIREBAUGH CANAL WATER DISTRICT
DECISION
ACCEPTANCE:
TIMING
QUALITY
SEPARATION:
DISTRICT LEVEL RECYCLING:
HOLDING:
ASSIMILATIVE WATER:
THE FARM
TILE WATER
TAILWATER
ALWAYS
SOMETIMES
NEVER
ALWAYS
SOMETIMES
NEVER
ANY
RESTRICTED
YES
NO
YES
TILE WATER
TILE & TAIL WATER
TAILWATER
ALWAYS
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SOMETIMES
NEVER
ALWAYS
SOMETIMES
NEVER
SAN JOAQUIN RIVER
BOTH
DISTRICT IRRIGATION SUPPLY
SAN JOAQUIN RIVER

Figure 10

There does not appear to be any formal decision making process regarding the amount of recycling. The recycling sumps are controlled automatically.

HOLDING

FCWD does not have an external holding facility.

ASSIMILATION WATER

FCWD does not have a formal policy regarding the use of the assimilative capacity of the San Joaquin River or the district. FCWD's DOPs discuss the continuing efforts to reduce the volume drainage water, but do not address total salt loading to the San Joaquin River, or how the district will coordinate with other drainers to meet water quality standards. The drainage and irrigation water supplies to FCWD are shown in **Table 6.**

Table 6
Drainage and Irrigation Water Supply
Firebaugh Canal Water District

Year	Delivered Water (AF)	Irrigated Acreage (Ac)	Tile Drainage Total (AF)	Drainage Out of Districts (AF)
1981	75,645	21,938		
1982	66,132	20,244		
1983	47,400	16,784		
1984	80,268	20,691		
1985	75,432	19,731		22,907
1986	62,966	19,825	3,537	31,191
1987	79,545	20,981	3,968	32,265
1988	75,106	23,282	3,698	26,041
1989	70,326	24,746	3,294	22,626
1990	63,903	25,458	3,363	16,964
1991	57,141	24,678	3,116	13,491
1992	59,569	24,894	3,045	13,491

Note: Drainage Out of District data is the combined drainage from FCWD, BWD and CCID-Camp 13. The data is from the monitoring point FC-5.

PACHECO WATER DISTRICT

IRRIGATION WATER DELIVERY

Pacheco Water District has water supply contracts with the CCID and the USBR. CCID water is pumped out of the Outside Canal into PoWD's Main Lift Canal. USBR water was originally delivered by pumping out of the DMC into the Main Lift Canal. Recently an outlet was constructed on the San Luis Canal east of PoWD at Eagle Field Road and the majority of the USBR supply now comes from this outlet.

There are several farmer owned wells within PoWD. These are used to supplement the surface water supply in years of curtailed allotment. Substantial pumping occurred in 1991 due to the drought and a reduction in USBR supplies. Some of this pumped water was directed to the DMC and used in other districts.

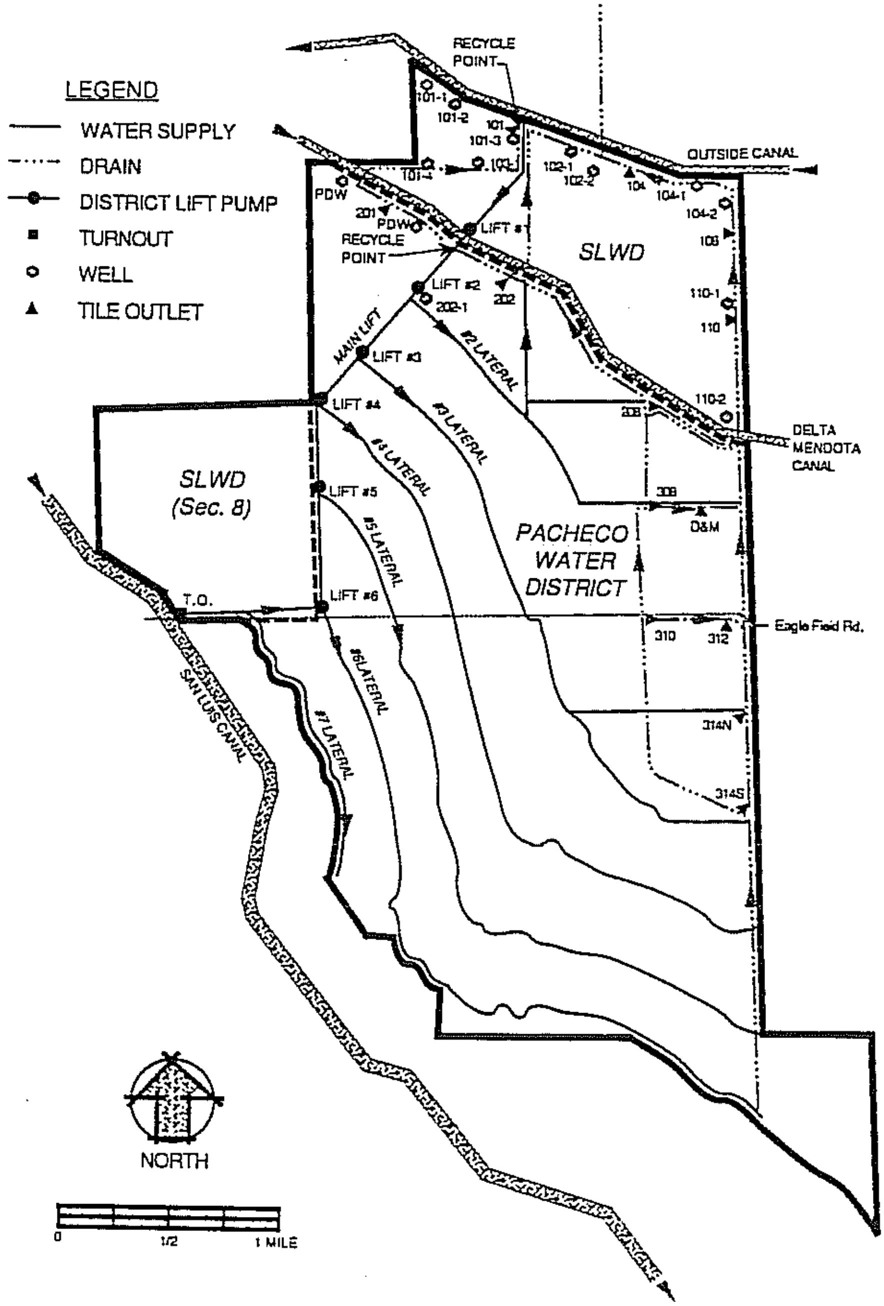
Referring to **Figure 11**, PoWD's water supply originally moved uphill from the Outside Canal and DMC in the Main Lift canal southwesterly through a series of six pump stations, Lifts #1 through #6. Water was directed into a series of six PoWD laterals to move by gravity southeasterly across the district. Gravity turnouts completed the delivery system to the individual fields.

With the installation of the San Luis Canal outlet, the majority of PoWD's water supply in a normal year comes from the San Luis Canal and flows by gravity down to the Main Lift Canal at the Lift #6 pump station. Water is diverted directly into Laterals #6 and #7. Water moves downhill through the Main Lift Canal northeasterly for distribution through Laterals #5, #4, #3, and #2.

Water is delivered to Section 8 of T12S, R11E, which lies outside of PoWD boundaries, through farmer owned ditches connected to the Main Lift Canal.

DRAINAGE DISPOSAL

PoWD maintains the drainage system and other lands that were originally part of Sam Hamburg Farms. There are approximately 5,900 acres drained, of which 4,400 acres are in PoWD.



PACHECO DRAINAGE AREA

Figure 11

Tile drain systems were first installed on farmland between the DMC and CCID's Outside Canal beginning in 1955. In 1962, installations began in fields south of the DMC. The last tile drain systems were installed in 1975. PoWD's 1985 WCP estimated that 2750 acres within the district and 933 acres outside of the district had tile drains installed. The drainage systems are owned and maintained by the landowners.

Tile water is collected at various sumps and pumped into a series of open drains. The drainage system, which consists of sumps, open drains, and outlet channel to GWD, are owned and maintained by PoWD.

The drainage system begins with a spill point at the end of Lateral #6 near the southeastern boundary of PoWD. The open drain flows north by gravity along the eastern boundary of PoWD. At sump 314S, the drain splits into two drains with the second drain paralleling the first about 1/2 mile west of the PoWD boundary. The second drain is reserved for tailwater only, while tile water is directed to the eastern boundary drain.

The eastern drain continues north to siphon under the DMC until it intercepts CCID's Outside Canal. There it turns west for approximately 3/4 of a mile to the PoWD outfall point. There it siphons under the Outside Canal into a pipeline and reappears at measuring point PO-1 as a concrete lined channel. This channel spills into the Main Drain that parallels CCID's Main Canal.

The second drain that splits off from the eastern boundary drain at sump 314S also flows north until it intercepts the DMC. It then flows northwesterly to where it intercepts the Main Lift Canal. There is a siphon under the DMC located at about tile sump 202. Drainage water flowing through this siphon will flow north until it intercepts CCID's Outside Canal. There it connects with the drain paralleling the Outside Canal. Drainage water can then move to the PoWD outfall point, siphon under the Outside Canal and flow to the Main Drain through measuring point PO-1.

There are two subsurface drain system collector sumps on the west side of the PoWD Main Lift Canal. Sump 101, which is located near the pumps on the Outside Canal, pumps across the Main Lift Canal to the drain paralleling the Outside Canal. Sump 201 pumps into an open drain paralleling the DMC. This drain siphons under the DMC then flows east to where it intercepts the Main Lift Canal. There it turns north to where it intercepts the CCID Outside Canal. Drainage water can be pumped over the Main Lift Canal into the parallel drain that siphons under the Outside Canal (this drain also connects with the two eastern boundary drains) and flow to the Main Drain through measuring point PO-1.

Thus, all drainage water from tile drains can flow to the Main Drain through PO-1.

Once in the Main Drain, PoWD drainage water will go through the GWD via either the Agatha or the Camp 13 Canals. (Refer to the section "Grassland Water District Drainage Operations" for a discussion of how agricultural drainage is moved through GWD). Drainage water from PoWD eventually enters the San Joaquin River through either Salt Slough or Mud Slough (North).

DISTRICT DRAINAGE POLICY

SUMMARY

PoWD's drainage policy (**Figure 12**) can be summarized according to the five policy levels as follows:

- **Acceptance.** PoWD will accept either tile water or tailwater.
- **Separation.** PoWD does attempt to separate tailwater and tile water.
- **District Level Recycling.** PoWD will recycle drainage water at a district level, but only for meeting peak irrigation water demands.
- **Holding.** PoWD does not have an external holding facility, except the drainage system itself.
- **Assimilation Water.** PoWD's DOPs indicate that it will maximize the assimilative capacity of the San Joaquin River. PoWD has used the assimilative capacity of the district in the past to meet water quality standards mandated by its contract with GWD.

ACCEPTANCE

PoWD will accept tile water or tailwater, but encourages on-farm recycling of tailwater.

SEPARATION

PoWD separates tile water from tailwater.

PACHECO WATER DISTRICT

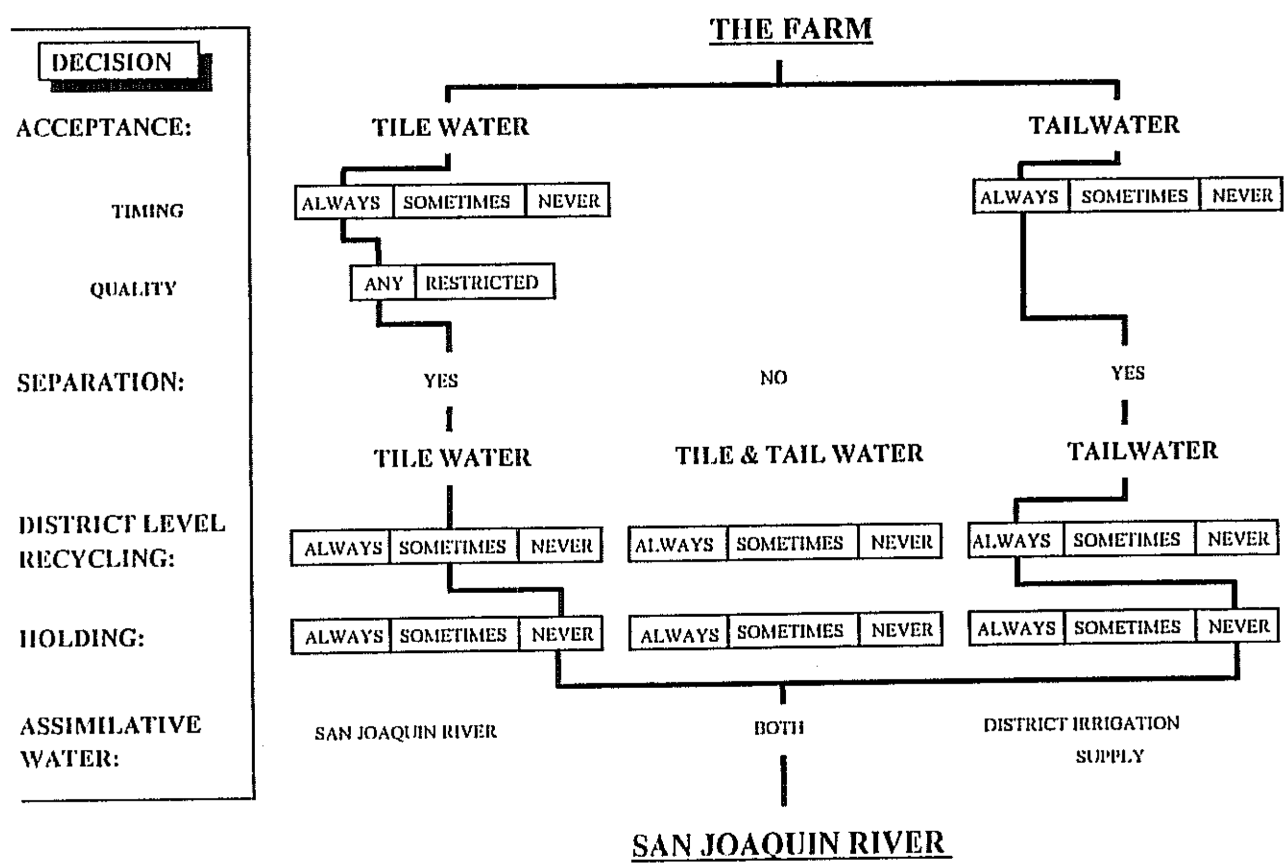


Figure 12

RECYCLING

Tile water and tailwater can be recycled by PoWD at two places. Much of the tailwater is captured immediately for use in downstream supply laterals before it reaches the drain system. Tailwater is not measured.

Note that all drainage water can end up in the drain east of the Main Lift Canal paralleling CCID's Outside Canal. There is a relatively flat gradient between the start of the Main Lift Canal and the drain siphon under the Outside Canal. Thus drainage water can either be turned north through point PO-1 for disposal through GWD to the San Joaquin River, or pumped back into the Main Lift Canal.

The second point of recycling is at the Lift #1 outlet works just south of the DMC. There are drains that parallel the DMC on both sides of the Main Lift Canal. Pumping works are in place that will allow drainage water from the northwest side of the Main Lift Canal to be transferred to the southeast side drain. The gradient in the southeast side drain is flat enough so that drainage water can be held for pumping up into the Main Lift Canal or turned through the siphon under the DMC to continue north. If it continues north, the drainage water will end up in the drain paralleling the CCID Outside Canal.

This point is the primary point for recycling of tailwater. Tile water normally flows to the drain paralleling CCID's Outside Canal for disposal through measuring point PO-1 and the GWD channels.

The recycling works are also owned and maintained by PoWD.

Originally, this system worked well to distribute the salt load from any recycled drainage water because irrigation water was moved uphill from Lift #1 to distribution through Laterals #2-7. The drainage water was blended with the entire fresh water supply as it was pumped out of the DMC and CCID's Outside Canal. Thus, recycled drainage water would be spread over the entire district.

Currently however, the majority of PoWD's supply comes from the new outlet on the San Luis Canal and flows by gravity northeasterly in the Main Lift Canal. Thus, drainage water that flows into the northern part of PoWD will tend to stay there resulting in a net movement of salt from the southern to the northern portion of PoWD. This curtails PoWD's recycling capability since a certain minimum water quality must be available to all farmers. Currently PoWD attempts to keep delivered water quality in the 900 to 1000 ppm TDS range with a maximum limit of 1400 ppm TDS.

PoWD is aware of the problems associated with concentrating salts in the northern portion of the district. The 1989, 1990, and 1991 DOPs discuss the installation of a system to pump drainage water to a mixing pond near the new San Luis Canal outlet. This would provide the maximum blending capacity to further reduce the required discharges to the San Joaquin River.

PoWD reported in its 1991 DOP that 1,500 acre-feet were recycled in 1990 and 2050 acre-feet in 1991. Blending and reuse are a management decision. There are three sets of criteria that govern the amount of recycling:

1. PoWD's contract with GWD allows PoWD drainage water to flow through GWD conveyance channels. An agreement was signed between Sam Hamburg Farms, predecessors to PoWD and PDD, and GWD in December, 1962. The agreement allows PoWD to discharge drainage water to the GWD. GWD can then use the water or convey it to the San Joaquin River at their discretion.

   The purpose of this agreement was to provide Sam Hamburg Farms with an outlet for their tile water and to provide a water supply for GWD. There were no firm water quality standards set forth in the original agreement.

   GWD (which consists primarily of wildfowl habitat) has not used PoWD drainage water since 1985, although they continue to convey the drainage water in their supply channels on its way to the San Joaquin River.

2. Agronomic considerations for PoWD crops in terms of both water supply and quality. In a normal year, PoWD is not concerned with total water supply. However, all growers are aware of the long term effects of a salt imbalance. As previously noted, the blending capabilities of PoWD are now constrained by the fact that all drainage water flows to the northern district and most of the fresh irrigation water supply comes in near the southern boundary. The district recycles drainage water as able, but attempts to deliver water of a certain minimum quality to the field.

3. Water quality standards set by the CVRWQCB for the San Joaquin River. In response to these standards, PoWD has drastically reduced the volume of drainage water to the San Joaquin River. Table 1, taken from the 1990 DOP, shows the reduction in total drainage water discharge. Some of this reduction is due to improved on-farm irrigation practices, which reduced tailwater. In addition, the drought has reduced the total water supply to the district in 1990 and 1991. The 1991 DOP estimates that 1,500 acre-feet of drainage water was recycled in 1990 and 2,050 acre-feet in 1991.

HOLDING

PoWD does not have an external holding facility except for the drainage system itself.

ASSIMILATION WATER

PoWD DOPs from 1989 through 1991 indicated that the criteria for recycling will be the available assimilative capacity of the San Joaquin River. The 1991 DOP includes a graph that specifically identifies the 1986-88 average discharge of selenium, the 1991 discharge, and the allowable discharge based on assimilative capacity in the San Joaquin River. Thus, in 1991, recycling was increased to improve a curtailed irrigation supply and to attempt to meet water quality standards in the San Joaquin River. The drainage and irrigation water supplies of the PoWD are shown in **Table 7.**

Table 7
Drainage and Irrigation Water Supply
Pacheco Water District

Year	Delivered Water (AF)	Irrigated Acreage (Ac)	Tile Drainage Total (AF)	Drainage Out of District (AF)
1981	12,653	4,410		
1982	9,763	4,410		
1983	9,751	3,696		
1984	10,775	3,696		
1985	9,000	3,100		2,531
1986	7,770	3,500		3,884
1987	9,756	4,028	5,717	5,176
1988	10,217	4,179	5,394	2,664
1989	13,063	3,648	6,609	5,122
1990	11,569	4,254	5,286	3,160
1991	11,572	4,369	5,624	2,716
1992	8,107	3,705	4,232	2,716

PANOCHE DRAINAGE DISTRICT

IRRIGATION WATER DELIVERY

Irrigation water supplies for fields in the Panoche Drainage District come from two sources. The water districts that make up PDD (Panoche Water District (PeWD), Oro Loma Water District, Eagle Field Water District, and Mercy Springs Water District) have water supply contracts with the USBR for delivery of Central Valley Project water. There are also forty-two farmer owned deep wells within PeWD, which is the main component of PDD.

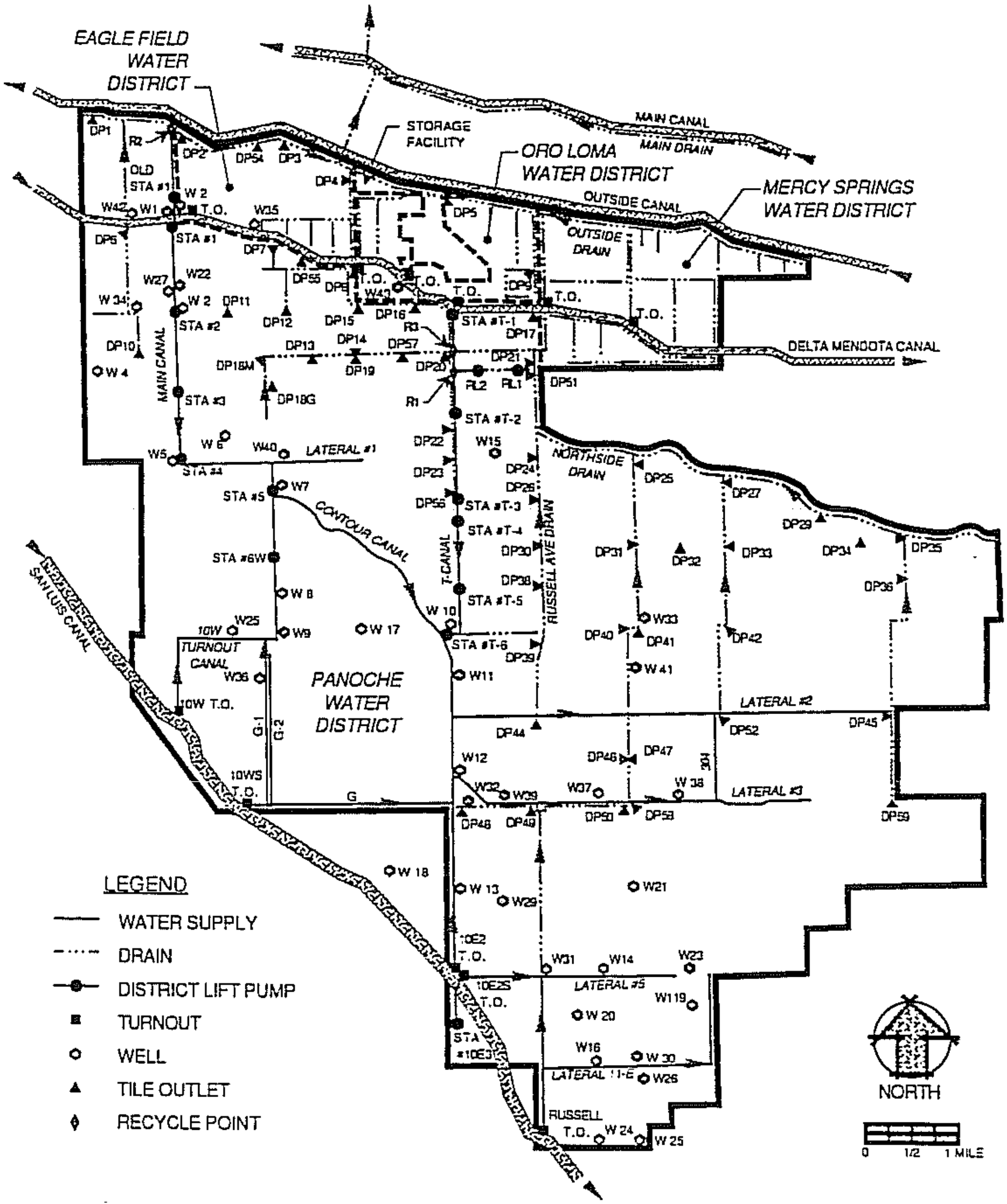
Originally, USBR supplies were delivered to PeWD from pump stations on the DMC. Three outlets were installed on the San Luis Canal with the construction of the State Water Project and the San Luis Unit. Fifty percent of PeWD's USBR contract water was delivered through these outlets. This significantly reduced PeWD's pumping costs. In 1991, one additional outlet on the San Luis Canal became operational and PeWD now estimates that seventy percent of USBR water is delivered from the San Luis Canal.

Water supplies to the other three water districts in PDD also come primarily from USBR contracts for DMC water.

Water from the DMC is pumped uphill through a series of lifts either on the Main Canal or the T-Canal. Water generally moves south and east along prevailing ground contours through a series of laterals as shown on **Figure 13**.

Water from the San Luis Canal is fed into the PeWD system at several points along the San Luis Canal; 10W TO #1, 10WS TO (the newest turnout), 10E2 TO #2, and Russell T.O. The use of San Luis Canal water significantly reduces pumping costs to PeWD and also provides higher quality water than the DMC.

Water is delivered from the PeWD laterals to individual farmers through both gravity outlets and low-lift pumps.



PANOCHE DRAINAGE DISTRICT

Figure 13

DRAINAGE DISPOSAL

The PDD is responsible for disposal of tailwater and tile water from PeWD, Eagle Field Water District, Oro Loma Water District, and Mercy Springs Water District. PDD's drainage system is a series of deep, open drain channels. These channels collect tile water from farmer owned tile systems and sumps, tailwater, and water from intercepted high water tables.

Drainage water generally moves northward until it ends up in the Outside Drain, which parallels the CCID Outside Canal. This drain siphons under the Outside Canal through PDD's main measuring point PE-14. From there the drainage water moves through the southern section of GWD. (See the section "Grassland Water District Drainage Operations" for a description of how agricultural drainage is conveyed through GWD canals). PDD drainage water eventually enters the San Joaquin River through either Salt Slough or Mud Slough (North).

DISTRICT DRAINAGE POLICY

SUMMARY

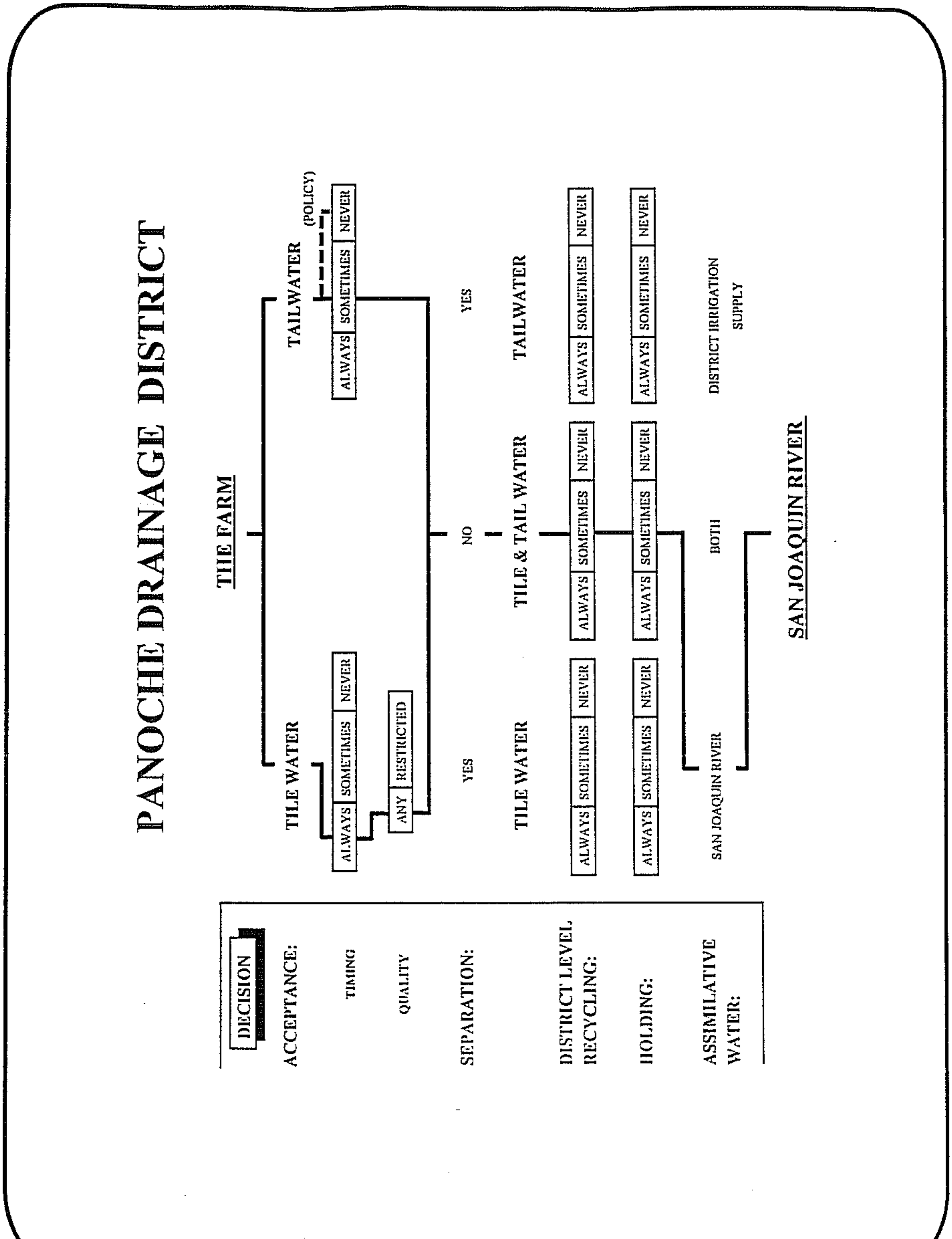
PDD's drainage policy (**Figure 14**) can be summarized according to the five policy levels as follows:

- **Acceptance-** PDD policy is not to accept tailwater. This policy is becoming more strictly enforced each year.

- **Separation-** PDD does not separate tile water from tailwater, when it does accept tailwater.

- **District Level Recycling-** PDD has recycled some drainage in the past year, but there is no formal policy in place. The amount of recycling is constrained by water quality downstream of the recycling points.

- **Holding-** PDD has constructed a small holding facility in order to store drainage during the flood-up of Grassland Water District. The facility is a pilot project to study feasibility.


PANOCHE DRAINAGE DISTRICT
DECISION
ACCEPTANCE:
TIMING
QUALITY
SEPARATION:
DISTRICT LEVEL RECYCLING:
HOLDING:
ASSIMILATIVE WATER:
THE FARM
TILE WATER
TAILWATER
(POLICY)
ALWAYS
SOMETIMES
NEVER
ALWAYS
SOMETIMES
NEVER
ANY
RESTRICTED
YES
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NEVER
SAN JOAQUIN RIVER
BOTH
DISTRICT IRRIGATION SUPPLY
SAN JOAQUIN RIVER

Figure 14

- **Assimilation Water-** PDD's DOPs indicate that it will maximize its use of the assimilative capacity of the San Joaquin River. There is no formal policy regarding the use of the district's assimilative capacity.

ACCEPTANCE

PDD's policy is not to accept tailwater. This policy has been adopted in the last two years. It is not yet strictly enforced to allow its members time to adapt to the change. However, it will be more strictly enforced in the future.

SEPARATION

With full enforcement of the "no tailwater" policy, PeWD will in effect separate tile water from tailwater. It does not do so at present.

RECYCLING

There are three locations where drainage water from PDD's system can be recycled into the PeWD supply laterals. These are shown as points R-1, R-2, and R-3 in **Figure 13**. The amount of recycling is constrained by the resulting water quality downstream of these recycling points. In their 1991 DOP, PDD reported recycling 400 acre-feet in water year 1990-91. In comparison, the USBR contract water supply for PeWD is 94,000 acre-feet annually.

Due to the difficulty in distributing the increased salt loads to all areas of the district, recycling is only part of the PDD strategy to meet water quality standards. Because of the layout of the supply and drain channels, the drainage water of large areas is currently being recycled into the supply for a much smaller area when recycling occurs.

HOLDING

PDD has recently installed an approximately 100 acre (300 acre-feet) external storage facility for drainage water. The storage site is shown as "Storage Facility" on **Figure 13**. Drainage water is stored during periods when Grassland Water District needs all its conveyance facilities to maximize flood-up using fresh water and acceptable quality drainage water. Following the flood-up, PDD drainage water will be released.

In its 1991 DOP, PDD also discussed a proposal whereby the subsurface drainage sumps would be operated in a sequential manner. This practice would store salts in the soil when there is no assimilative capacity in the San Joaquin River. However, PDD notes several operational questions concerning this practice that have not been resolved to their satisfaction. It is unknown when, if ever, this practice would be adopted.

ASSIMILATION WATER

PDD's current strategy for meeting the water quality standards in the San Joaquin River rests on selenium removal processes (which are still in field testing), temporary storage of drainage water (either externally or internally), and maximum use of the assimilative capacity of the San Joaquin River. The drainage and irrigation water supplies of the PDD are shown in **Table 8.**

PDD/GWD DRAINAGE AGREEMENT

PDD has an agreement with GWD that allows them to convey their drainage water through GWD. The original intent of the PDD/GWD agreement was to provide PDD with an outlet for its drainage, and thus the ability to maintain a salt balance, and to provide an additional water supply to GWD, which was, and is, chronically short of water.

GWD (which is primarily composed of wildfowl habitat) has not used PDD drain water since 1985. GWD continues to convey the drain water in their supply channels on its way to the San Joaquin River.

Table 8
Drainage and Irrigation Water Supply
Panoche Drainage District

Year	Delivered Water (AF)	Irrigated Acreage (Ac)	Tile Drainage Total (AF)	Drainage Out of District (AF)
1981	97,344	34,151		34,411
1982	89,155	19,986		34,861
1983	75,306	29,703		43,278
1984	109,511	30,754		38,359
1985	98,241	33,375		30,468
1986	92,487	33,153		33,257
1987	98,119	32,208		34,724
1988	97,196	33,795		30,144
1989	91,300	35,686		24,875
1990	81,258	31,799		19,835
1991	69,706	28,126	3,295	13,475
1992	63,416	27,742	6,715	13,532

GRASSLAND WATER DISTRICT DRAINAGE OPERATIONS

The lands of Grassland Water District are divided into a northern and a southern section as shown in **Figure 15**. All of the agricultural drainage water from PoWD, PDD, CDD, and BWD that flows to the San Joaquin River must move through GWD channels. In addition, a major portion of FCWD drainage water and that from CCID's Camp 13 Study Area move through GWD.

Except for drainage water from CDD, drainage water flows into the Main Drain that parallels CCID's Main Canal between GWD's Agatha and Camp 13 Canals. Agricultural drainage water may flow through the southern portion of GWD through the Agatha or Camp 13 Canals depending on GWD operations. GWD can turn all agricultural drainage water through the Agatha Canal while delivering fresh water supplies (delivered from CCID's Main Canal) through the Camp 13 Canal, or vice-versa.

This system of alternating fresh water and drainage water in the two canals is termed "Flip-Flop" by the area drainers. It is necessitated by the selenium content of the agricultural drainage water. Prior to 1985, GWD would utilize agricultural drainage water for irrigation and "fall flood up" (flooding of the duck ponds in anticipation of migrations on the Pacific Flyway). As a result of the problems at Kesterson Reservoir the USFWS issued water quality guidelines for habitat use. In 1989, the SWRCB adopted a 2 ppb selenium standard for water used by GWD. Since 1985, GWD has not used agricultural drainage water.

However, a large part of GWD's total water supply was this agricultural drainage water. Out of necessity, the agricultural districts continue to drain through GWD channels. This maintains agricultural productivity while providing GWD with enough revenues to allow it to buy fresh water when available. The "Flip-Flop" system allows agricultural drainage to continue while simultaneously allowing GWD to deliver fresh water, when available, to its own users.

Both the Agatha and Camp 13 Canals eventually drain into Mud Slough (South) which in turns drains into the Santa Fe Canal. The Santa Fe flows northwesterly and eventually meets the San Luis Canal. Drainage water can continue north through the Santa Fe Canal, which eventually spills into Mud Slough (North). Mud Slough (North) then spills to the San Joaquin River. If required by GWD operations, drainage water can be diverted north through the San Luis Canal and discharged through the City Gates to Mud Slough (South). Mud Slough (South) spills into Salt Slough which in turn spills into the San Joaquin River.

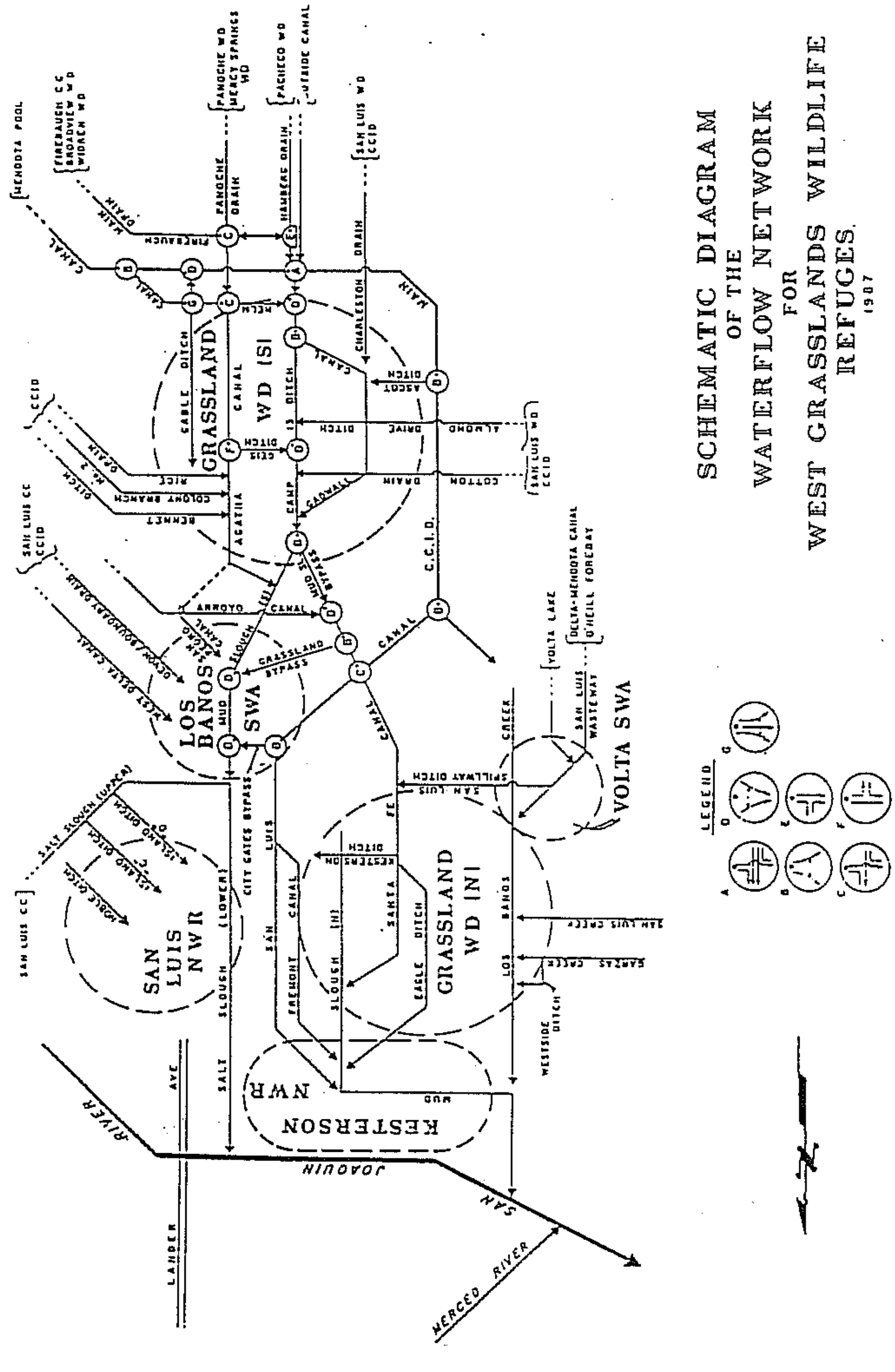

SCHEMATIC DIAGRAM
OF THE
WATERFLOW NETWORK
FOR
WEST GRASSLANDS WILDLIFE
REFUGES
1987
GRASSLAND WD (S)
LOS BANOS SWA
VOLTA SWA
SAN LUIS NWR
GRASSLAND WD (N)
KESTERSON NWR
SAN JOAQUIN RIVER
MERCED RIVER
LANDER AVE
LEGEND

Figure 15

There is a temporary cross connection, termed the "Blake-Porter Bypass", that is located just upstream of the confluence of the Santa Fe and San Luis Canals. This connection can be used to turn drainage water in the Santa Fe Canal into the Boundary Drain, which is owned by San Luis Canal Company. The bypass allows GWD to convey fresh water into its northern section while agricultural drainage water still flows to the San Joaquin River.

The Boundary Drain spills into Salt Slough which in turn terminates at the San Joaquin River. Thus, agricultural drainage water from PoWD, PDD, BWD, CCID's Camp 13 Study Area, and a portion of FCWD eventually enters the San Joaquin River through either Salt Slough or Mud Slough (North).

The drainage water from CDD takes a slightly different route. The CDD drainage water outfall spills to GWD's Gadwall Canal. The Gadwall Canal spills into Mud Slough (South). At this point, CCD drainage water joins with the drainage water from the other upslope agricultural districts. Mud Slough (South) then spills into the Santa Fe Canal upstream of the Blake-Porter Bypass.

DRAINAGE OPERATIONS SUMMARY

SUMMARY OF STUDY AREA

Table 9 summarizes district policies in terms of the five decision levels and also the amount of recycling and drainage currently occurring (as estimated by the districts).

Table 9

Summary of Drainage Policies and Recycling of Various Districts

District	Acceptance	Separation	Drainage Water Recycling Percentage Based on the Total Drainage Volume[1] On-Farm Level Tail	On-Farm Level Tile	District Level Tail	District Level Tile	Holding	Assimilation
BWD[2]	Both	None	13	0	50	50	No holding policy or facility	No policy, now using SJR. Can add 10-25 CFS for dilution
CCID[5]	Both	None	8	0	10	10	No holding policy or facility	No policy, now using SJR
CDD[3]	Both	Separate upslope side of DMS, blend on downslope	0	0	0	0	No holding policy or facility	Use SJR to maximum, not a supply district
FCWD	Both	None	13	0	5	30	No holding policy or facility	No policy, now using SJR
PDD[4]	Tile only	None	90	5	1	4	100 acre holding pond	Use SJR to maximum, not a supply district
PoWD	Both	Separate	94	0	94	55	No holding policy or facility	Use SJR to maximum, has used district capacity

Notes:

1. On-farm estimates are based upon the acreage served with on-farm recycling systems, because on-farm return systems are rarely metered. Numbers will vary from year to year. Data generally reflects 1991 conditions.
2. BWD provides drainage for the FDA consisting of BWD and approximately 2230 acres (1991), 1,590 acres (1992 and 1993), 0 acres (1994) laying outside of BWD.
3. CDD consists of lands laying in CCID and SLWD. (4275 acres supplied by SLWD; 500 acres supplied by CCID water).
4. PDD consists of Panoche, Oro Loma, Eagle Field, and Mercy Springs Water Districts.
5. Only 1 of 10 active tile pumps recycles into outside Canal.

ACCEPTANCE

All districts are currently accepting both tile water and tailwater. However, PDD's formal policy is to not accept tailwater and that policy will soon be completely enforced. BWD has plans for installing a new turnout on the San Luis Canal. If this installation is completed, BWD will no longer accept tailwater either. Although this report does not include detailed information about on-farm recycling, there is already considerable on-farm recycling of tailwater in the study region.

SEPARATION

CDD's drainage system keeps tile water separate from tailwater on the upslope side of the DMC. Once pumped across the DMC, tile water and tailwater are commingled in the open drains. PoWD is attempting to keep tile water and tailwater separated. All other districts commingle tile water and tailwater.

DISTRICT LEVEL RECYCLING

CDD does not recycle any drainage water at the district level. CCID, while recycling substantial amounts of drainage water in other parts of their system, is recycling only one tile sump of ten in the 6,000 acre Camp 13 Study Area. PeWD has only recycled drainage water in the past year, and then only approximately 500 acre-feet. PoWD, and BWD recycle substantial amounts of drainage water.

HOLDING

Only PeWD has an external holding facility, and this is only a pilot project.

ASSIMILATION WATER

CCID has indicated that it can blend its problem drainage water with its own irrigation water. FCWD and BWD have not indicated what their formal policies will be in the future. CDD, PDD, and PoWD have indicated that they will maximize their use of the San Joaquin River's assimilative capacity.

Formal policies are lacking at all districts that would govern the extent of recycling, the allowable water quality limits for blended irrigation water, and division of the assimilative capacity of the San Joaquin River among the area drainers.

AMOUNT OF RECYCLING, DRAINAGE, AND WATER SUPPLIES

Obviously the on-going drought has had an impact on the amount of recycling and drainage. It is impossible to accurately predict district operations in a normal year. Looking at pre-drought years would probably not be appropriate due to the change in the political/regulatory climate regarding agricultural drainage in the area.

RECOMMENDATIONS

The recommendations in this section are based upon the following assumptions:

- The water quality in the San Joaquin River will deteriorate in the future rather than improve.
- Districts will be required to have a formal policy regarding the technical decisions of timing and water quality releases to the San Joaquin River.
- Future water supplies to the districts will continue to be lower than historical (prior to 1985) averages.
- Districts must consistently maintain a low ECe in the soil in order to farm high value crops.

These assumptions lead to the conclusion that salt releases to the San Joaquin River will be carefully controlled in the future. Furthermore, the districts must have the ability to respond quickly to varying San Joaquin River water qualities. The result of these assumptions and conclusions is a recommended **Drainage District Decision Tree** which is shown in **Figure 2.**

ACCEPTANCE

Districts should not accept any tailwater. All surface runoff should be recycled on-farm. This will maximize district control over problem drainage water. This also will maintain maximum fresh water supplies for growers, especially in the case of boron and selenium laden tile water. In those cases where existing district facilities allow separation of tile water and tailwater, acceptance of tailwater may continue if desired. Some tile systems may have high quality (ie., low salinity) discharges. In order to minimize the size of holding ponds, only tile water with at least some predetermined EC or selenium concentration should be accepted. For example, tile water with an EC of less than 5.0 dS/m might be rejected by the district. This value can change with time, depending upon the available storage in the holding reservoir.

SEPARATION

In all cases, tile water should be kept separate from tailwater.

DISTRICT LEVEL RECYCLING

Recycling facilities should be in place to allow recycling of tile water as water quality allows or operations require. Recycling when water quality allows will maintain maximum DIEs. Recycling may be required when assimilative capacity is not available and external holding facilities are full. Recycling of tile water throughout the entire district will tend to "average out" the soil EC's. Recycling pipelines or ditches must terminate at irrigation water inlets to the districts so that drainage water will mix in all areas.

HOLDING

Depending on the anticipated salt load, and especially loads of constituents such as selenium, boron, molybdenum, and arsenic, external holding facilities will probably be warranted. If salts have to be temporarily stored when assimilative capacity is not available, external storage minimizes response time when assimilative capacity does become available. Also, in this situation, external storage continually maintains acceptable agricultural productivity (because of maintaining both required leaching fractions and sufficient rootzones.)

ASSIMILATION WATER

The extent of the use of fresh water flows of the San Joaquin River, or irrigation water that has to be conveyed through the San Joaquin/Sacramento Delta for the express purpose of diluting agricultural drainage so as to maintain water quality standards in the San Joaquin River, is a political/regulatory decision.

FUTURE

In the future, formal rules must be defined by each district which address the following issues:

- If the water quality of received tile water is an occasional barrier to meeting San Joaquin River water quality standards, there should be written guidelines for acceptable EC of tile water.

- If recycling of tile water (via district irrigation canals) is to be a normal occurrence, there should be written guidelines governing the limits of water quality to be delivered to any one farmer in the district. No farmer should be asked to take more salt than any other, without some compensation.

- Holding facilities will be necessary if assimilative capacity will be limited at any time. One of the limits on assimilative capacity will be fresh water flows in the San Joaquin River, if the assimilative capacity of the San Joaquin River is to be used. There should be written guidelines that govern the use of the assimilative capacity of the San Joaquin River. These guidelines must be agreeable to the CVRWQCB, the Grassland Drainers, and all downstream users. They will be based upon specific monitoring locations, water qualities, and river flow rates.

- If there is no external holding facility and the assimilative capacity of the district is to be used, there should be some mechanism in place to predict the need and availability of the district's assimilative capacity. It may also be desirable to perform daily predictions (not control) of on-farm irrigation schedules on a district-wide basis. Some districts, notably BWD, CCID, and FCWD may have sufficient supplies available to blend.

GEOGRAPHICAL INFORMATION SYSTEM (GIS)

A Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. Simply put, the GIS is a computer system capable of holding and using data describing places on the earth's surface. Data that a GIS can store and use can be represented as related data layers including, hydrology, topography, land use, utilities, soils, streets, districts, and parcels. A GIS was created for the study area.

A GIS differs from other computer programs, such as, spreadsheets, statistics packages, or drafting programs in that a GIS allows spatial operations to be done on the data. Other program packages are only capable of answering aspatial queries, or questions not requiring the stored value of latitude and longitude or describing where places are in relation to each other. A GIS readily answers spatial queries.

The GIS database was updated and utilized several times throughout the course of this project. The database has been transmitted to the USBR (through Internet), USSL in Riverside (tape file), and to the USGS in Sacramento (tape file). Copies of the file can be made for other entities wishing to perform analysis of the study area using GIS. **Appendix** A includes a detailed description of the GIS developed for this project.

An ARC/INFO database has been developed for this project to manage all of the map data. Although initial maps were down-loaded from the Bureau of Reclamation's computer in Sacramento at the start of the project, many changes to the existing data were found to be necessary. Therefore, data was re-digitized from existing map sources and field checking using a USGS 7.5 minute quad series as the base. The quads are as follows:

Charleston School	Mendota Dam	Laguna Seca
Dos Palos	Firebaugh	
Oxalis	Broadview Farms	
Poso Farm	Hammonds Ranch	

These maps were supplemented with field information and other map bases received from various agencies. The GIS database presently contains basic information. The location data has been used extensively to generate maps and determine the physical interrelationships between districts. Parameters have been assigned to each of the input points and segments (such as the length and direction of flow). However, detailed information has not been incorporated into the database. For example, the monthly solute loadings for each sump for the 12 year study period are available in computer spreadsheet files. These files contain a tremendous amount of data that has not been filtered nor added to the ARCINFO database. As other entities utilize the database to expand the analysis of the study area, that data will be retrieved and used to update (and expand) the master files maintained at Cal Poly.

SUBSURFACE FLOW ANALYSIS

An estimate of subsurface flows was needed to estimate several components of the water balance. The subsurface lateral flow between districts, and the vertical flow to the deep aquifer. Estimates of these values were obtained from John Fio (personal communication). John Fio, with the USGS in Sacramento, used the GIS to perform an analysis of the base flow for the study area. The sump discharge data for all of the sumps in the study area was analyzed for the study period. Fio's analysis and data is included in **Appendix H.** Low flows have been assumed to approximate the most accurate determination of the base flow. The base flow was defined for this study as the net groundwater inflow to the region from outside of the study area boundaries measured in the surface discharge measurements during the nonirrigated periods.

Sump discharge data from Broadview, CCID-Camp 13, Charleston, Firebaugh, Pacheco, and Panoche districts was obatined and formatted to a single spreadsheet application. High flows (January through September - in general) were separated from low flows during the non-irrigated time of the year (October-December).

The data collection effort uncovered an important recommendation for future activities for the districts. All data should be reported in a consistent format with well-defined protocols for data srorage and retrieval. For example, all data could be provided in ASCII format. Retrieval of the raw data was a significant amount of the expense for this portion of the study due to differences in reporting formats, embedded graphs, and programmed cell formulas.

The estimated lowflow in 1992 (most complete data set) was as follows; Broadview-52 AF, CCID C13-No Estimate, Charleston-30 AF, Firebaugh-409 AF, Pacheco-575 AF, Panoche-970 AF. The estimated total flow for these sumps was as follows; Broadview-853 AF, CCID C13-No Estimate, Charleston-320 AF, Firebaugh-3,045 AF, Pacheco-4,232 AF, Panoche-6,715 AF. The total low flow volume was 2,036 AF for the entire study area. The taoal flows (The total sump flow was estimated at 15,165 AF. The low flow represents about 13% of the total sump flow for the study area. The low flow total would respresent a minimum base flow since it does not account for baseflow during the irrigation months. This means that about 13% of the sump drainwater volumes placed into drains is from outside of the study area.

An estimate of incidental recharge below the Corcoran clay was also required for the water balance in this study. Preliminary results from a steady-state groundwater-flow model construicted by Fio (in review) indicate the following simulated incidental recharge to the aquifer below the Corcoran Clay; Panoche-0.54 AF/yr, Broadview-0.31 AF/yr, Firebaugh-.26 AF/yr.

Well pumping estimates were made by contacting individual growers in the study area. It was not possible to obtain values that were reasonable. Estimates of groundwater pumping were made by evaluating the ETc requirements. This was significant for Panoche Drainage District in 1991 and 1992 where groundwater pumping represented about 30% of the water supply.

SECTION 3

DISTRICT IRRIGATION EFFICIENCY: ETc APPROACH

OVERVIEW

The 1991 DIE Report (Burt et al, 1991) calculated district irrigation efficiencies using a number of definitions for four water districts in the Los Banos area; Broadview Water District, Firebaugh Canal Water District, Panoche Water District, and Pacheco Water District. A second report was completed in 1992 (Burt et al, 1992) which examined DIE's for two more districts; Charleston Drainage District and an approximately 5,000 acre subarea of Central California Irrigation District, often referred to as Camp 13. In addition, due to slight changes in the manner in which effective rainfall and crop water usage were calculated, the 1992 DIE Report recalculated the efficiencies for the original four districts. Particular attention was paid to PoWD which was seen to be at a much lower efficiency than the others in the previous study.

This study represents the 1993 DIE Report and is a further refinement of the previous two reports. Some of the added analysis includes a scrutiny of the water delivery and acreage data supplied by the districts. Some of the data was supplied as water delivered to the individual turnouts instead of to the district. Some of the data was supplied as water year or crop year instead of calendar year. This report changed the basis for the time frame of the analysis. This report uses a water year, or October 1 to September 30 timeline. This allowed a more ready backcheck of data against the RWQCB, USBR, and other data sources.

Also included was a refinement of the method of handling effective precipitation and leaching requirement. Based on an extensive analysis of the pre-plant irrigation efficiencies, it was determined that previous methods to determine effective precipitation quantities were overestimating the benefit of the rainfall.

Since 1985, additional data has been collected and reported for the drainage volumes discharged by the districts. Using this data and some assumptions regarding subsurface water flows, an estimate of the irrigation efficiency using a "bathtub" or water balance approach was completed in order to verify the validity of the values generated by the theoretical ETc approach. The water balance approach is described in the next section of the report.

District Irrigation Efficiency is defined as:

$$\text{DIE} = \frac{\text{Applied Irrigation Water which is Beneficially Used} \times 100}{\text{Applied Irrigation Water}}$$

Where;

The boundary of beneficial use is the district. "Beneficial use of applied irrigation water" includes crop ET, leaching to maintain a salt balance, and leaching for reclamation. "Applied irrigation water" refers to water entering the district boundaries including contract water, district/grower wells, upwards flux into the root zone of groundwater originating from outside the district, and surface inflows from outside the district. Rainfall can be either surface runoff or infiltrated soil moisture that could end up as crop ETc, salt balance leaching, reclamation leaching, or non-beneficial deep percolation.

The DIE values were determined for water years 1981 to 1992 depending on what information was available. In this report, 1981 refers to the water year October 1, 1980 through September 30, 1981. The goal was to identify the relative level of DIE and any trends up or down. Another goal was to determine the maximum attainable irrigation efficiencies.

DATA ANALYSIS - ETc APPROACH

The following describes the process used to determine the district irrigation efficiency of the various districts. It is described in **levels** for the general objectives. The detailed information discussed in this section required to calculate the final DIE values is described in **steps**.

Level I: Data requirements identified.

- Estimates of ETo (CIMIS)
- Crop coefficient (Kc) curves for the different crops
- Estimates of Kc reductions due to uneven growth
- Acreages for the different crops by year
- Water supplies into the districts
- Water quality delivered to the farm

- Estimates of gross rainfall
- Estimates of effective rainfall

Level II: Sources for the required data identified.

- The Districts themselves, including personal conversations, searches of water delivery records, the DOP's submitted to the CVRWCQB, the annual crop and water supply reports to the USBR (for Reclamation Districts), and the 1985 WCP's submitted to the USBR (for Reclamation Districts).
- The USBR for their records of water deliveries through the DMC and the San Luis Canal (California Aqueduct).
- The DWR sponsored CIMIS network for ETo and gross rainfall information.
- The University of California and USSL, technical publications, and private consultants for crop coefficient curves and salinity-tolerance data.
- The USBR and DWR for functions relating effective and gross rainfall.

Level III: Initial data transformations are done.

- Step 1: Assess Kc values for crops
- Step 2: Report ETo from CIMIS. Estimate years where data not available.
- Step 3: Calculate annual ETc based on ETo and crop coefficients
- Step 4: Report irrigated acreage for each District
- Step 5: Calculate crop water use
- Step 6: Calculations of effective rainfall
- Step 7: Report the water delivered for each district
- Step 8: Calculations of leaching requirements

Level IV: The estimate of DIE are determined based on the definition of beneficial use and delivered water. The beneficial use for each crop and the water supplies to the districts are calculated. This value is represented by the sum of the crop ETc and the leaching requirement less the amount of water supplied by effective precipitation. This report uses 50% of the total rainfall during October through March as effective rain.

- Step 9: Calculate the District Irrigation Efficiency (DIE)

Level VI: A check of calculated expected drainage is compared to the measured drainage through Grassland Water District. Level VI is discussed in section 5.

PROCEDURE

A single spreadsheet was developed for the entire study area using the ETc approach. The spreadsheet is available in PC-Compatible format or Macintosh format. The entire spreadsheet in its original format is included in **Appendix** D.

STEP 1: Crop Coefficients

Determination of the crop coefficients.

The crop coefficient is a dimensionless number (usually between 0.0 and 1.2) that is multiplied by the reference evapotranspiration (ETo) value to arrive at a crop evapotranspiration (ETc) estimate. Average crop coefficients were determined from various sources including DWR published values, the University of California Cooperative Extension, locally developed Kc's and Kc's reported from Westlands Water District. The daily values used for each of the crops in this report are included in **Appendix B**. The following table are the monthly Kc's used in this report.

Table 10
Monthly Crop Kc Values

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Fallow	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Misc.	0.00	0.00	0.00	0.06	0.30	0.59	1.02	0.92	0.00	0.00	0.00	0.00
Cotton	0.05	0.00	0.00	0.00	0.00	0.00	0.10	0.23	0.70	1.03	1.02	0.56
Alfalfa	0.79	0.57	0.36	0.25	0.32	0.82	0.90	0.90	0.90	0.90	0.90	0.90
Wheat	0.00	0.04	0.23	0.54	0.95	1.17	1.04	0.47	0.00	0.00	0.00	0.00
Melons	0.00	0.00	0.00	0.00	0.00	0.04	0.18	0.43	0.94	0.18	0.00	0.00
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.05	0.24	0.40	0.90	1.10	0.85	0.00
Sugar Beets	1.10	1.10	1.10	1.10	1.04	0.44	0.00	0.13	0.38	0.96	1.10	1.10
Barley	0.00	0.03	0.23	0.53	0.93	1.15	0.98	0.30	0.00	0.00	0.00	0.00
Beans	0.00	0.00	0.00	0.00	0.00	0.03	0.14	0.78	1.14	0.56	0.00	0.00
Seed Alf.	0.00	0.03	0.20	0.24	0.47	0.74	0.97	0.97	0.66	0.19	0.00	0.00
Rice	0.00	0.00	0.00	0.00	0.00	0.19	0.95	1.14	1.25	1.17	1.02	0.00
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.36	0.88	1.10	0.93	0.27
Vegetable	0.00	0.00	0.00	0.06	0.30	0.59	1.02	0.92	0.00	0.00	0.00	0.00
Pasture	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Stonefruit	0.89	0.00	0.00	0.00	0.00	0.50	0.78	0.89	0.98	0.98	0.98	0.97
Walnut/Apple	0.42	0.06	0.00	0.00	0.00	0.54	0.84	0.95	1.06	1.14	1.09	0.77
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.16	0.51	1.04	0.93	0.59

Upon evaluation of aerial photography and site visits, it was determined that maximum Kc's were not being achieved in the study area due to stunted growth and bare ground spots included in the acreage figures. A detailed visual analysis of the crops was completed to determine the impact. Slides of each section in the study area were evaluated and assessed a reduction factor. The overall reduction factor was 86%. All of the Kc values were multiplied by 86% to reflect the reduction in crop water use due to stunted growth and bare ground.

STEP 2: ETo

Obtain the reference evapotranspiration (ETo) values.

ETo was obtained from the CIMIS database in Sacramento. Reference Evapotranspiration (ETo) is a term used to estimate the ET rate of a reference crop. The reference crop used for the CIMIS program is grass, which is close clipped, actively growing, completely shading the soil, and well watered. Data for this study was obtained from the CIMIS station #7 located near Firebaugh, California. The station is located on the Tellis Ranch and was activated in September of 1982. Values for 1981 and 1982 were from the 1983 set of data. The following table summarizes the values reported for the ETo. Note that the ETo does not vary significantly on a year to year basis.

Table 11
Monthly ETo (in Inches) at CIMIS Station #7, Telles Ranch

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1981*	3.83	1.96	1.14	1.19	2.05	3.80	5.75	7.70	8.45	8.50	7.09	5.43	57
1982*	3.83	1.96	1.14	1.19	2.05	3.80	5.75	7.70	8.45	8.50	7.09	5.43	57
1983	3.83	1.96	1.14	0.85	1.80	3.00	4.84	8.80	9.57	9.24	7.48	5.73	58
1984	3.45	1.35	0.95	0.98	2.16	4.60	5.77	8.96	8.55	8.57	7.11	6.28	59
1985	3.83	1.75	1.74	0.96	2.37	3.53	6.43	7.56	8.57	8.19	7.19	5.40	58
1986	3.88	1.81	0.77	1.24	2.03	3.50	5.59	7.50	8.04	7.90	7.30	5.07	55
1987	4.02	2.54	0.73	1.32	1.71	3.78	6.65	7.71	8.29	8.25	7.06	5.40	57
1988	3.66	1.62	1.39	1.21	2.65	5.20	4.98	7.25	7.47	8.40	6.72	5.31	56
1989	3.30	1.59	0.94	1.49	1.70	3.83	5.75	7.86	8.58	8.95	7.40	5.12	57
1990	3.94	1.98	1.05	1.34	1.94	3.76	6.14	7.02	8.44	8.46	7.03	5.41	57
1991	4.44	2.55	1.51	1.31	2.09	2.97	5.61	6.66	8.57	8.57	6.51	5.15	56
1992	3.96	2.44	1.17	0.73	1.81	3.01	5.81	8.12	7.74	7.94	7.52	5.69	56
Average	3.83	1.96	1.14	1.15	2.03	3.73	5.76	7.74	8.39	8.46	7.12	5.45	56.7

* Note: 1981 and 1982 are average values.

STEP 3: ETc

Calculation of the crop ETc.

The annual crop ETc was obtained by summing the calculated monthly ETo values reported by CIMIS by the Kc values for each crop. The equation for ETc is:

ETc = Kc x Factor (stunted growth) x ETo

Where, ETc = Monthly crop evapotranspiration

Kc = Average monthly crop coefficient

Factor = Adjustment factor for stunted growth and bare spots (86%)

ETo = Monthly reference evapotranspiration (grass reference)

The following table represents the average ETc for the entire study time from of 1981 through 1992. For this report, each year was evaluated individually. Tables 13 through 24 represent the ETc calculated for each year.

Table 12
Average Monthly ETc (in Inches): 1981-1992

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Inches
Fallow	0.20	0.10	0.06	0.06	0.10	0.19	0.30	0.40	0.43	0.44	0.37	0.28	**3**
Misc.	0.00	0.00	0.00	0.06	0.52	1.89	5.05	6.13	0.00	0.00	0.00	0.00	**14**
Cotton	0.16	0.00	0.00	0.00	0.00	0.00	0.51	1.50	5.03	7.50	6.25	2.65	**24**
Alfalfa	2.60	0.97	0.35	0.25	0.57	2.63	4.46	5.99	6.50	6.55	5.51	4.22	**41**
Wheat	0.00	0.06	0.22	0.53	1.66	3.75	5.17	3.12	0.00	0.00	0.00	0.00	**15**
Melons	0.00	0.00	0.00	0.00	0.00	0.11	0.89	2.89	6.80	1.33	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.15	1.19	2.65	6.52	8.00	5.20	0.00	**24**
Sugar Beets	3.62	1.85	1.08	1.09	1.82	1.42	0.00	0.84	2.76	7.00	6.74	5.16	**33**
Barley	0.00	0.06	0.22	0.52	1.63	3.69	4.87	1.99	0.00	0.00	0.00	0.00	**13**
Beans	0.00	0.00	0.00	0.00	0.00	0.09	0.69	5.18	8.20	4.09	0.00	0.00	**18**
Seed Alf.	0.00	0.06	0.20	0.24	0.82	2.36	4.82	6.45	4.79	1.40	0.00	0.00	**21**
Rice	0.00	0.00	0.00	0.00	0.00	0.60	4.73	7.59	9.02	8.54	6.26	0.00	**37**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.61	2.37	6.33	8.00	5.71	1.29	**24**
Vegetable	0.00	0.00	0.00	0.06	0.52	1.89	5.05	6.13	0.00	0.00	0.00	0.00	**14**
Pasture	2.97	1.52	0.88	0.89	1.57	2.89	4.46	5.99	6.50	6.55	5.51	4.22	**44**
Stonefruit	2.94	0.00	0.00	0.00	0.00	1.60	3.88	5.95	7.04	7.13	6.00	4.54	**39**
Walnut/Apple	1.39	0.10	0.00	0.00	0.00	1.72	4.14	6.31	7.65	8.27	6.68	3.61	**40**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.06	3.66	7.59	5.67	2.79	**21**

Table 13
Monthly ETc (in Inches): 1981

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.20	0.10	0.06	0.06	0.11	0.20	0.30	0.40	0.44	0.44	0.37	0.28	**3**
Misc.	0.00	0.00	0.00	0.06	0.53	1.93	5.04	6.10	0.00	0.00	0.00	0.00	**14**
Cotton	0.16	0.00	0.00	0.00	0.00	0.00	0.51	1.49	5.07	7.54	6.22	2.64	**24**
Alfalfa	2.60	0.97	0.35	0.26	0.57	2.67	4.45	5.96	6.54	6.58	5.49	4.20	**41**
Wheat	0.00	0.06	0.22	0.55	1.67	3.82	5.17	3.11	0.00	0.00	0.00	0.00	**15**
Melons	0.00	0.00	0.00	0.00	0.00	0.12	0.89	2.88	6.85	1.34	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.15	1.19	2.64	6.56	8.04	5.17	0.00	**24**
Sugar Beets	3.62	1.85	1.08	1.12	1.83	1.45	0.00	0.84	2.78	7.04	6.71	5.14	**33**
Barley	0.00	0.06	0.22	0.54	1.65	3.75	4.86	1.98	0.00	0.00	0.00	0.00	**13**
Beans	0.00	0.00	0.00	0.00	0.00	0.09	0.69	5.16	8.26	4.12	0.00	0.00	**18**
Seed Alf.	0.00	0.06	0.20	0.25	0.83	2.40	4.82	6.42	4.83	1.41	0.00	0.00	**21**
Rice	0.00	0.00	0.00	0.00	0.00	0.61	4.72	7.55	9.09	8.58	6.23	0.00	**37**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.61	2.36	6.38	8.04	5.68	1.28	**24**
Vegetable	0.00	0.00	0.00	0.06	0.53	1.93	5.04	6.10	0.00	0.00	0.00	0.00	**14**
Pasture	2.97	1.52	0.88	0.92	1.59	2.94	4.45	5.96	6.54	6.58	5.49	4.20	**44**
Stonefruit	2.94	0.00	0.00	0.00	0.00	1.63	3.88	5.92	7.09	7.17	5.97	4.52	**39**
Walnut/Apple	1.39	0.10	0.00	0.00	0.00	1.75	4.14	6.28	7.70	8.32	6.65	3.60	**40**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.06	3.69	7.64	5.64	2.77	**21**

Table 14
Monthly ETc (in Inches): 1982

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.20	0.10	0.06	0.06	0.11	0.20	0.30	0.40	0.44	0.44	0.37	0.28	**3**
Misc.	0.00	0.00	0.00	0.06	0.53	1.93	5.04	6.10	0.00	0.00	0.00	0.00	**14**
Cotton	0.16	0.00	0.00	0.00	0.00	0.00	0.51	1.49	5.07	7.54	6.22	2.64	**24**
Alfalfa	2.60	0.97	0.35	0.26	0.57	2.67	4.45	5.96	6.54	6.58	5.49	4.20	**41**
Wheat	0.00	0.06	0.22	0.55	1.67	3.82	5.17	3.11	0.00	0.00	0.00	0.00	**15**
Melons	0.00	0.00	0.00	0.00	0.00	0.12	0.89	2.88	6.85	1.34	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.15	1.19	2.64	6.56	8.04	5.17	0.00	**24**
Sugar Beets	3.62	1.85	1.08	1.12	1.83	1.45	0.00	0.84	2.78	7.04	6.71	5.14	**33**
Barley	0.00	0.06	0.22	0.54	1.65	3.75	4.86	1.98	0.00	0.00	0.00	0.00	**13**
Beans	0.00	0.00	0.00	0.00	0.00	0.09	0.69	5.16	8.26	4.12	0.00	0.00	**18**
Seed Alf.	0.00	0.06	0.20	0.25	0.83	2.40	4.82	6.42	4.83	1.41	0.00	0.00	**21**
Rice	0.00	0.00	0.00	0.00	0.00	0.61	4.72	7.55	9.09	8.58	6.23	0.00	**37**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.61	2.36	6.38	8.04	5.68	1.28	**24**
Vegetable	0.00	0.00	0.00	0.06	0.53	1.93	5.04	6.10	0.00	0.00	0.00	0.00	**14**
Pasture	2.97	1.52	0.88	0.92	1.59	2.94	4.45	5.96	6.54	6.58	5.49	4.20	**44**
Stonefruit	2.94	0.00	0.00	0.00	0.00	1.63	3.88	5.92	7.09	7.17	5.97	4.52	**39**
Walnut/Apple	1.39	0.10	0.00	0.00	0.00	1.75	4.14	6.28	7.70	8.32	6.65	3.60	**40**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.06	3.69	7.64	5.64	2.77	**21**

Table 15
Monthly ETc (in Inches): 1983

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.20	0.10	0.06	0.04	0.09	0.15	0.25	0.45	0.49	0.48	0.39	0.30	**3**
Misc.	0.00	0.00	0.00	0.04	0.46	1.52	4.24	6.97	0.00	0.00	0.00	0.00	**13**
Cotton	0.16	0.00	0.00	0.00	0.00	0.00	0.43	1.71	5.74	8.20	6.56	2.78	**26**
Alfalfa	2.60	0.97	0.35	0.18	0.50	2.11	3.75	6.81	7.41	7.15	5.79	4.44	**42**
Wheat	0.00	0.06	0.22	0.39	1.47	3.02	4.35	3.55	0.00	0.00	0.00	0.00	**13**
Melons	0.00	0.00	0.00	0.00	0.00	0.09	0.75	3.29	7.75	1.46	0.00	0.00	**13**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.12	1.00	3.02	7.43	8.74	5.46	0.00	**26**
Sugar Beets	3.62	1.85	1.08	0.80	1.61	1.14	0.00	0.96	3.15	7.65	7.08	5.42	**34**
Barley	0.00	0.06	0.22	0.39	1.45	2.96	4.09	2.27	0.00	0.00	0.00	0.00	**11**
Beans	0.00	0.00	0.00	0.00	0.00	0.07	0.58	5.89	9.35	4.47	0.00	0.00	**20**
Seed Alf.	0.00	0.06	0.20	0.18	0.73	1.90	4.05	7.33	5.46	1.54	0.00	0.00	**21**
Rice	0.00	0.00	0.00	0.00	0.00	0.48	3.97	8.63	10.29	9.33	6.58	0.00	**39**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.51	2.70	7.22	8.74	5.99	1.35	**27**
Vegetable	0.00	0.00	0.00	0.04	0.46	1.52	4.24	6.97	0.00	0.00	0.00	0.00	**13**
Pasture	2.97	1.52	0.88	0.66	1.39	2.32	3.75	6.81	7.41	7.15	5.79	4.44	**45**
Stonefruit	2.94	0.00	0.00	0.00	0.00	1.29	3.26	6.76	8.03	7.79	6.30	4.77	**41**
Walnut/Apple	1.39	0.10	0.00	0.00	0.00	1.38	3.48	7.17	8.72	9.04	7.01	3.80	**42**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.13	1.21	4.17	8.30	5.95	2.93	**23**

Table 16
Monthly ETc (in Inches): 1984

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.18	0.07	0.05	0.05	0.11	0.24	0.30	0.46	0.44	0.44	0.37	0.32	**3**
Misc.	0.00	0.00	0.00	0.05	0.56	2.33	5.06	7.10	0.00	0.00	0.00	0.00	**15**
Cotton	0.14	0.00	0.00	0.00	0.00	0.00	0.52	1.74	5.13	7.60	6.24	3.05	**24**
Alfalfa	2.34	0.67	0.29	0.21	0.60	3.24	4.47	6.94	6.62	6.63	5.50	4.86	**42**
Wheat	0.00	0.04	0.19	0.45	1.76	4.62	5.18	3.62	0.00	0.00	0.00	0.00	**16**
Melons	0.00	0.00	0.00	0.00	0.00	0.14	0.89	3.35	6.92	1.35	0.00	0.00	**13**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.19	1.19	3.07	6.64	8.11	5.19	0.00	**24**
Sugar Beets	3.26	1.28	0.90	0.93	1.93	1.75	0.00	0.97	2.81	7.10	6.73	5.94	**34**
Barley	0.00	0.04	0.19	0.45	1.74	4.54	4.88	2.31	0.00	0.00	0.00	0.00	**14**
Beans	0.00	0.00	0.00	0.00	0.00	0.11	0.69	6.00	8.36	4.15	0.00	0.00	**19**
Seed Alf.	0.00	0.04	0.16	0.20	0.88	2.91	4.83	7.47	4.88	1.42	0.00	0.00	**23**
Rice	0.00	0.00	0.00	0.00	0.00	0.74	4.74	8.79	9.19	8.65	6.25	0.00	**38**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.61	2.75	6.45	8.11	5.70	1.48	**25**
Vegetable	0.00	0.00	0.00	0.05	0.56	2.33	5.06	7.10	0.00	0.00	0.00	0.00	**15**
Pasture	2.67	1.04	0.74	0.76	1.67	3.56	4.47	6.94	6.62	6.63	5.50	4.86	**45**
Stonefruit	2.65	0.00	0.00	0.00	0.00	1.97	3.89	6.89	7.17	7.22	5.99	5.22	**41**
Walnut/Apple	1.25	0.07	0.00	0.00	0.00	2.12	4.15	7.30	7.79	8.38	6.67	4.16	**42**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.23	3.73	7.69	5.66	3.21	**22**

Table 17
Monthly ETc (in Inches): 1985

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.20	0.09	0.09	0.05	0.12	0.18	0.33	0.39	0.44	0.42	0.37	0.28	**3**
Misc.	0.00	0.00	0.00	0.05	0.61	1.79	5.64	5.99	0.00	0.00	0.00	0.00	**14**
Cotton	0.16	0.00	0.00	0.00	0.00	0.00	0.58	1.47	5.14	7.27	6.31	2.62	**24**
Alfalfa	2.59	0.86	0.54	0.21	0.66	2.48	4.98	5.85	6.63	6.34	5.57	4.18	**41**
Wheat	0.00	0.05	0.34	0.44	1.94	3.55	5.77	3.05	0.00	0.00	0.00	0.00	**15**
Melons	0.00	0.00	0.00	0.00	0.00	0.11	1.00	2.83	6.94	1.29	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.14	1.33	2.59	6.65	7.75	5.24	0.00	**24**
Sugar Beets	3.62	1.66	1.65	0.91	2.12	1.35	0.00	0.82	2.82	6.78	6.80	5.11	**34**
Barley	0.00	0.05	0.34	0.44	1.90	3.49	5.44	1.95	0.00	0.00	0.00	0.00	**14**
Beans	0.00	0.00	0.00	0.00	0.00	0.08	0.77	5.06	8.38	3.96	0.00	0.00	**18**
Seed Alf.	0.00	0.05	0.30	0.20	0.96	2.24	5.38	6.30	4.89	1.36	0.00	0.00	**22**
Rice	0.00	0.00	0.00	0.00	0.00	0.57	5.28	7.41	9.21	8.27	6.32	0.00	**37**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.68	2.32	6.46	7.75	5.76	1.27	**24**
Vegetable	0.00	0.00	0.00	0.05	0.61	1.79	5.64	5.99	0.00	0.00	0.00	0.00	**14**
Pasture	2.96	1.35	1.35	0.74	1.83	2.73	4.98	5.85	6.63	6.34	5.57	4.18	**45**
Stonefruit	2.94	0.00	0.00	0.00	0.00	1.51	4.33	5.81	7.19	6.90	6.06	4.49	**39**
Walnut/Apple	1.39	0.09	0.00	0.00	0.00	1.62	4.62	6.16	7.81	8.01	6.74	3.58	**40**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.18	1.04	3.74	7.35	5.72	2.76	**21**

Table 18
Monthly ETc (in Inches): 1986

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.20	0.09	0.04	0.06	0.10	0.18	0.29	0.39	0.41	0.41	0.38	0.26	**3**
Misc.	0.00	0.00	0.00	0.06	0.52	1.78	4.90	5.94	0.00	0.00	0.00	0.00	**13**
Cotton	0.16	0.00	0.00	0.00	0.00	0.00	0.50	1.45	4.82	7.01	6.41	2.46	**23**
Alfalfa	2.63	0.89	0.24	0.27	0.57	2.46	4.33	5.81	6.22	6.11	5.65	3.92	**39**
Wheat	0.00	0.06	0.15	0.57	1.66	3.52	5.02	3.03	0.00	0.00	0.00	0.00	**14**
Melons	0.00	0.00	0.00	0.00	0.00	0.11	0.87	2.80	6.51	1.25	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.14	1.15	2.57	6.24	7.47	5.32	0.00	**23**
Sugar Beets	3.67	1.71	0.73	1.17	1.82	1.33	0.00	0.82	2.64	6.54	6.91	4.80	**32**
Barley	0.00	0.05	0.15	0.57	1.63	3.46	4.73	1.93	0.00	0.00	0.00	0.00	**13**
Beans	0.00	0.00	0.00	0.00	0.00	0.08	0.67	5.02	7.86	3.82	0.00	0.00	**17**
Seed Alf.	0.00	0.05	0.13	0.26	0.82	2.22	4.68	6.25	4.59	1.31	0.00	0.00	**20**
Rice	0.00	0.00	0.00	0.00	0.00	0.56	4.59	7.36	8.64	7.98	6.42	0.00	**36**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.59	2.30	6.06	7.47	5.85	1.20	**23**
Vegetable	0.00	0.00	0.00	0.06	0.52	1.78	4.90	5.94	0.00	0.00	0.00	0.00	**13**
Pasture	3.00	1.40	0.60	0.96	1.57	2.71	4.33	5.81	6.22	6.11	5.65	3.92	**42**
Stonefruit	2.98	0.00	0.00	0.00	0.00	1.50	3.77	5.77	6.75	6.66	6.15	4.22	**38**
Walnut/Apple	1.41	0.09	0.00	0.00	0.00	1.61	4.02	6.11	7.33	7.73	6.84	3.36	**39**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.15	1.03	3.51	7.09	5.81	2.59	**20**

Table 19
Monthly ETc (in Inches): 1987

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.21	0.13	0.04	0.07	0.09	0.20	0.34	0.40	0.43	0.43	0.36	0.28	**3**
Misc.	0.00	0.00	0.00	0.07	0.44	1.92	5.83	6.11	0.00	0.00	0.00	0.00	**14**
Cotton	0.17	0.00	0.00	0.00	0.00	0.00	0.59	1.49	4.97	7.32	6.19	2.62	**23**
Alfalfa	2.72	1.25	0.23	0.28	0.48	2.66	5.15	5.97	6.42	6.39	5.46	4.18	**41**
Wheat	0.00	0.08	0.14	0.61	1.40	3.80	5.97	3.11	0.00	0.00	0.00	0.00	**15**
Melons	0.00	0.00	0.00	0.00	0.00	0.12	1.03	2.88	6.71	1.30	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.15	1.37	2.64	6.43	7.80	5.15	0.00	**24**
Sugar Beets	3.80	2.40	0.69	1.25	1.53	1.44	0.00	0.84	2.73	6.83	6.68	5.11	**33**
Barley	0.00	0.07	0.14	0.60	1.37	3.73	5.62	1.99	0.00	0.00	0.00	0.00	**14**
Beans	0.00	0.00	0.00	0.00	0.00	0.09	0.80	5.16	8.10	3.99	0.00	0.00	**18**
Seed Alf.	0.00	0.07	0.13	0.27	0.69	2.39	5.57	6.43	4.73	1.37	0.00	0.00	**22**
Rice	0.00	0.00	0.00	0.00	0.00	0.61	5.46	7.56	8.91	8.33	6.21	0.00	**37**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.70	2.37	6.25	7.80	5.66	1.27	**24**
Vegetable	0.00	0.00	0.00	0.07	0.44	1.92	5.83	6.11	0.00	0.00	0.00	0.00	**14**
Pasture	3.11	1.97	0.57	1.02	1.32	2.93	5.15	5.97	6.42	6.39	5.46	4.18	**44**
Stonefruit	3.09	0.00	0.00	0.00	0.00	1.62	4.48	5.93	6.96	6.95	5.95	4.49	**39**
Walnut/Apple	1.46	0.13	0.00	0.00	0.00	1.74	4.78	6.29	7.56	8.07	6.62	3.58	**40**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.18	1.06	3.62	7.41	5.62	2.76	**21**

Table 20
Monthly ETc (in Inches): 1988

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.19	0.08	0.07	0.06	0.14	0.27	0.26	0.37	0.39	0.43	0.35	0.27	**3**
Misc.	0.00	0.00	0.00	0.06	0.68	2.64	4.37	5.74	0.00	0.00	0.00	0.00	**13**
Cotton	0.15	0.00	0.00	0.00	0.00	0.00	0.45	1.41	4.48	7.45	5.90	2.58	**22**
Alfalfa	2.48	0.80	0.43	0.26	0.74	3.66	3.85	5.61	5.78	6.50	5.20	4.11	**39**
Wheat	0.00	0.05	0.27	0.56	2.16	5.23	4.47	2.93	0.00	0.00	0.00	0.00	**16**
Melons	0.00	0.00	0.00	0.00	0.00	0.16	0.77	2.71	6.05	1.32	0.00	0.00	**11**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.21	1.03	2.49	5.80	7.95	4.90	0.00	**22**
Sugar Beets	3.46	1.53	1.31	1.14	2.37	1.98	0.00	0.79	2.46	6.96	6.36	5.02	**33**
Barley	0.00	0.05	0.27	0.55	2.13	5.14	4.21	1.87	0.00	0.00	0.00	0.00	**14**
Beans	0.00	0.00	0.00	0.00	0.00	0.12	0.60	4.85	7.30	4.07	0.00	0.00	**17**
Seed Alf.	0.00	0.05	0.24	0.25	1.08	3.29	4.17	6.04	4.26	1.40	0.00	0.00	**21**
Rice	0.00	0.00	0.00	0.00	0.00	0.84	4.09	7.11	8.03	8.48	5.91	0.00	**34**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.52	2.23	5.63	7.95	5.38	1.25	**23**
Vegetable	0.00	0.00	0.00	0.06	0.68	2.64	4.37	5.74	0.00	0.00	0.00	0.00	**13**
Pasture	2.83	1.25	1.08	0.94	2.05	4.02	3.85	5.61	5.78	6.50	5.20	4.11	**43**
Stonefruit	2.81	0.00	0.00	0.00	0.00	2.23	3.36	5.57	6.27	7.08	5.66	4.42	**37**
Walnut/Apple	1.33	0.08	0.00	0.00	0.00	2.39	3.58	5.91	6.81	8.22	6.30	3.52	**38**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.14	1.00	3.26	7.54	5.35	2.71	**20**

Table 21
Monthly ETc (in Inches): 1989

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.17	0.08	0.05	0.08	0.09	0.20	0.30	0.41	0.44	0.46	0.38	0.26	**3**
Misc.	0.00	0.00	0.00	0.08	0.44	1.94	5.04	6.22	0.00	0.00	0.00	0.00	**14**
Cotton	0.14	0.00	0.00	0.00	0.00	0.00	0.51	1.52	5.14	7.94	6.49	2.49	**24**
Alfalfa	2.24	0.79	0.29	0.32	0.47	2.70	4.45	6.08	6.64	6.93	5.73	3.96	**41**
Wheat	0.00	0.05	0.19	0.69	1.39	3.85	5.16	3.17	0.00	0.00	0.00	0.00	**14**
Melons	0.00	0.00	0.00	0.00	0.00	0.12	0.89	2.94	6.95	1.41	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.16	1.19	2.70	6.66	8.47	5.40	0.00	**25**
Sugar Beets	3.12	1.50	0.89	1.41	1.52	1.46	0.00	0.86	2.82	7.41	7.00	4.84	**33**
Barley	0.00	0.05	0.19	0.68	1.37	3.78	4.86	2.02	0.00	0.00	0.00	0.00	**13**
Beans	0.00	0.00	0.00	0.00	0.00	0.09	0.69	5.26	8.38	4.33	0.00	0.00	**19**
Seed Alf.	0.00	0.04	0.16	0.31	0.69	2.43	4.81	6.55	4.90	1.49	0.00	0.00	**21**
Rice	0.00	0.00	0.00	0.00	0.00	0.62	4.72	7.71	9.22	9.04	6.51	0.00	**38**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.61	2.41	6.47	8.47	5.93	1.21	**25**
Vegetable	0.00	0.00	0.00	0.08	0.44	1.94	5.04	6.22	0.00	0.00	0.00	0.00	**14**
Pasture	2.55	1.23	0.73	1.15	1.32	2.96	4.45	6.08	6.64	6.93	5.73	3.96	**44**
Stonefruit	2.53	0.00	0.00	0.00	0.00	1.64	3.88	6.04	7.20	7.54	6.24	4.26	**39**
Walnut/Apple	1.20	0.08	0.00	0.00	0.00	1.76	4.13	6.41	7.82	8.75	6.94	3.39	**40**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.08	3.74	8.04	5.89	2.62	**22**

Table 22
Monthly ETc (in Inches): 1990

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.20	0.10	0.05	0.07	0.10	0.19	0.32	0.36	0.44	0.44	0.36	0.28	**3**
Misc.	0.00	0.00	0.00	0.07	0.50	1.91	5.38	5.56	0.00	0.00	0.00	0.00	**13**
Cotton	0.16	0.00	0.00	0.00	0.00	0.00	0.55	1.36	5.06	7.51	6.17	2.63	**23**
Alfalfa	2.67	0.98	0.33	0.29	0.54	2.65	4.75	5.43	6.53	6.55	5.44	4.19	**40**
Wheat	0.00	0.06	0.21	0.62	1.58	3.78	5.51	2.83	0.00	0.00	0.00	0.00	**15**
Melons	0.00	0.00	0.00	0.00	0.00	0.11	0.95	2.62	6.83	1.33	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.15	1.27	2.41	6.55	8.00	5.13	0.00	**24**
Sugar Beets	3.73	1.87	0.99	1.27	1.74	1.43	0.00	0.76	2.77	7.01	6.65	5.12	**33**
Barley	0.00	0.06	0.21	0.61	1.56	3.71	5.19	1.81	0.00	0.00	0.00	0.00	**13**
Beans	0.00	0.00	0.00	0.00	0.00	0.09	0.74	4.70	8.25	4.10	0.00	0.00	**18**
Seed Alf.	0.00	0.06	0.18	0.28	0.79	2.38	5.14	5.85	4.82	1.41	0.00	0.00	**21**
Rice	0.00	0.00	0.00	0.00	0.00	0.61	5.04	6.88	9.07	8.54	6.18	0.00	**36**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.65	2.15	6.37	8.00	5.63	1.28	**24**
Vegetable	0.00	0.00	0.00	0.07	0.50	1.91	5.38	5.56	0.00	0.00	0.00	0.00	**13**
Pasture	3.05	1.53	0.81	1.04	1.50	2.91	4.75	5.43	6.53	6.55	5.44	4.19	**44**
Stonefruit	3.02	0.00	0.00	0.00	0.00	1.61	4.14	5.40	7.08	7.13	5.92	4.50	**39**
Walnut/Apple	1.43	0.10	0.00	0.00	0.00	1.73	4.41	5.72	7.69	8.28	6.59	3.58	**40**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.97	3.68	7.60	5.60	2.76	**21**

Table 23
Monthly ETc (in Inches): 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.23	0.13	0.08	0.07	0.11	0.15	0.29	0.34	0.44	0.44	0.34	0.27	**3**
Misc.	0.00	0.00	0.00	0.07	0.54	1.51	4.92	5.27	0.00	0.00	0.00	0.00	**12**
Cotton	0.19	0.00	0.00	0.00	0.00	0.00	0.50	1.29	5.14	7.60	5.71	2.50	**23**
Alfalfa	3.01	1.26	0.47	0.28	0.58	2.09	4.34	5.15	6.63	6.63	5.04	3.99	**39**
Wheat	0.00	0.08	0.30	0.60	1.71	2.99	5.04	2.69	0.00	0.00	0.00	0.00	**13**
Melons	0.00	0.00	0.00	0.00	0.00	0.09	0.87	2.49	6.94	1.35	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.12	1.16	2.28	6.65	8.11	4.75	0.00	**23**
Sugar Beets	4.20	2.41	1.43	1.24	1.87	1.13	0.00	0.72	2.82	7.10	6.16	4.87	**34**
Barley	0.00	0.07	0.30	0.60	1.68	2.93	4.74	1.72	0.00	0.00	0.00	0.00	**12**
Beans	0.00	0.00	0.00	0.00	0.00	0.07	0.68	4.46	8.38	4.15	0.00	0.00	**18**
Seed Alf.	0.00	0.07	0.26	0.27	0.85	1.88	4.70	5.55	4.89	1.42	0.00	0.00	**20**
Rice	0.00	0.00	0.00	0.00	0.00	0.48	4.61	6.53	9.21	8.65	5.72	0.00	**35**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.59	2.04	6.46	8.11	5.22	1.22	**24**
Vegetable	0.00	0.00	0.00	0.07	0.54	1.51	4.92	5.27	0.00	0.00	0.00	0.00	**12**
Pasture	3.44	1.97	1.17	1.01	1.62	2.30	4.34	5.15	6.63	6.63	5.04	3.99	**43**
Stonefruit	3.41	0.00	0.00	0.00	0.00	1.27	3.78	5.12	7.19	7.22	5.49	4.28	**38**
Walnut/Apple	1.61	0.13	0.00	0.00	0.00	1.37	4.03	5.43	7.81	8.38	6.10	3.41	**38**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.92	3.74	7.69	5.18	2.63	**20**

Table 24
Monthly ETc (in Inches): 1992

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Fallow	0.20	0.13	0.06	0.04	0.09	0.16	0.30	0.42	0.40	0.41	0.39	0.29	**3**
Misc.	0.00	0.00	0.00	0.04	0.47	1.53	5.09	6.43	0.00	0.00	0.00	0.00	**14**
Cotton	0.17	0.00	0.00	0.00	0.00	0.00	0.52	1.57	4.64	7.04	6.60	2.76	**23**
Alfalfa	2.68	1.20	0.36	0.16	0.51	2.12	4.50	6.28	5.99	6.15	5.82	4.40	**40**
Wheat	0.00	0.08	0.23	0.34	1.48	3.03	5.22	3.28	0.00	0.00	0.00	0.00	**14**
Melons	0.00	0.00	0.00	0.00	0.00	0.09	0.90	3.04	6.27	1.25	0.00	0.00	**12**
Process Tom.	0.00	0.00	0.00	0.00	0.00	0.12	1.20	2.78	6.01	7.51	5.48	0.00	**23**
Sugar Beets	3.75	2.31	1.11	0.69	1.62	1.15	0.00	0.88	2.54	6.58	7.11	5.38	**33**
Barley	0.00	0.07	0.23	0.33	1.45	2.97	4.91	2.09	0.00	0.00	0.00	0.00	**12**
Beans	0.00	0.00	0.00	0.00	0.00	0.07	0.70	5.44	7.56	3.84	0.00	0.00	**18**
Seed Alf.	0.00	0.07	0.20	0.15	0.74	1.91	4.86	6.77	4.42	1.32	0.00	0.00	**20**
Rice	0.00	0.00	0.00	0.00	0.00	0.48	4.77	7.96	8.32	8.02	6.61	0.00	**36**
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.61	2.49	5.84	7.51	6.02	1.34	**24**
Vegetable	0.00	0.00	0.00	0.04	0.47	1.53	5.09	6.43	0.00	0.00	0.00	0.00	**14**
Pasture	3.07	1.89	0.91	0.57	1.40	2.33	4.50	6.28	5.99	6.15	5.82	4.40	**43**
Stonefruit	3.04	0.00	0.00	0.00	0.00	1.29	3.92	6.24	6.49	6.69	6.34	4.73	**39**
Walnut/Apple	1.44	0.12	0.00	0.00	0.00	1.39	4.18	6.62	7.05	7.77	7.05	3.77	**39**
Sorghum	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.12	3.38	7.13	5.99	2.91	**21**

STEP 4: Irrigated Acreage

Report the irrigated acreage values.

Irrigated acreage was reported for the water year in most cases. Some of the districts report acreage based on a calendar year. Some of the districts report acreage based on March through Febnruary. The data reported represents the most accurate data available. In order to standardized the reporting of information, some of the crops were grouped together. For example, carrots might be separated by the individual districts but would combined with other crops in the "vegetable" category.

BROADVIEW WATER DISTRICT: IRRIGATED ACREAGE

Table 25 is a summary of the acreages of the various crops for the years studied. Acreage data is recorded by the district based on a water year format (October through September). There was no reported acreage for the following crops; corn, vegetables, pasture, stonefruit, walnut/apple, or sorghum. Note the fallow acreage increases in 1991 and 1992 due to the drought. Note the substantial decrease in the cotton acreage in 1983 due to the PIC program.

Table 25
Acreage's of Crops for BWD: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	0	334	3,790	95	345	854	1,128	531	452	799	3,460	4,602
Misc.	290	300	0	140	150	140	75	0	147	0	50	148
Cotton	5,669	5,283	2,035	4,905	4,037	4,231	3,721	4,348	4,649	4,416	3,828	2,257
Alfalfa	0	0	160	160	150	147	0	0	0	0	41	0
Wheat	1,046	1,149	835	900	983	968	1,160	689	708	903	304	0
Melons	0	455	450	300	790	670	1,080	1,535	1,279	814	198	448
Process Tom.	220	0	300	150	750	750	450	680	840	850	662	1,080
Sugar Beets	0	300	300	1,355	750	425	300	454	150	300	0	0
Barley	547	741	250	190	425	113	54	150	41	292	0	0
Beans	623	40	745	300	0	20	0	175	0	0	0	0
Seed Alf.	630	560	435	560	630	705	1,030	705	694	585	456	550
Rice	0	0	0	0	0	0	0	0	178	0	0	
Corn	0	0	0	0	0	0	0	0	0	0	0	0
Vegetable	0	0	0	0	0	0	0	0	0	0	0	0
Pasture	0	0	0	0	0	0	0	0	0	0	0	0
Stonefruit	0	0	0	0	0	0	0	0	0	0	0	0
Walnut/Apple	0	0	0	0	0	0	0	0	0	0	0	0
Sorghum	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	9,025	8,828	5,510	8,960	8,665	8,169	7,870	8,736	8,686	8,160	5,539	4,483

CCID-CAMP13: IRRIGATED ACREAGE

Approximately 5000 acres of a portion of the Central California Irrigation District was included in this study. This area is refered to as the Camp 13 area. This area was isolated due to low water quality being pumped from the tile drain systems.

Table 26 is a summary of the acreages of the various crops for the years studied. Acreage data is recorded by the district based on a water year format (October through September). There was no reported acreage for the following crops; processing tomatos, beans, seed alfalfa, vegetables, pasture, stonefruit, walnut/apple, or sorghum. In 1981 through 1984, data was not available from the district. Average values were used for these years.

Table 26
Acreages of Crops for CCID-Camp 13: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	161	161	161	161	318	729	677	146	58	0	0	0
Misc.	0	0	0	0	0	0	0	0	0	0	0	0
Cotton	1,049	1,049	1,049	1,049	1,675	1,431	1,537	1,389	1,547	1,443	1,835	1,733
Alfalfa	288	288	288	288	0	0	340	485	551	551	745	784
Wheat	391	391	391	391	1,073	497	925	790	322	601	0	487
Melons	54	54	54	54	251	0	132	46	46	117	0	61
Process Tom.	0	0	0	0	0	0	0	0	0	0	0	0
Sugar Beets	764	764	764	764	1,970	1,485	556	1,462	1,245	806	863	782
Barley	56	56	56	56	0	0	0	0	0	0	319	351
Beans	0	0	0	0	0	0	0	0	0	0	0	0
Seed Alf.	0	0	0	0	0	0	0	0	0	0	0	0
Rice	540	540	540	540	442	1,039	1,452	1,047	355	720	793	630
Corn	41	41	41	41	0	88	130	0	0	198	0	72
Vegetable	0	0	0	0	0	0	0	0	0	0	0	0
Pasture	0	0	0	0	0	0	0	0	0	0	0	0
Stonefruit	0	0	0	0	0	0	0	0	0	0	0	0
Walnut/Apple	0	0	0	0	0	0	0	0	0	0	0	0
Sorghum	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3,183	3,183	3,183	3,183	5,411	4,540	5,072	5,219	4,066	4,436	4,555	4,900

CHARLESTON DRAINAGE DISTRICT: IRRIGATED ACREAGE

Approximately 5000 acres of a portion of the Central California Irrigation District was included in this study. This area is refered to as the Camp 13 area. This area was isolated due to low water quality being pumped from the tile drain systems.

Table 27 is a summary of the acreages of the various crops for the years studied. Acreage data is recorded by the district based on a water year format (October through September). There was no reported acreage for the following crops; wheat, seed alfalfa, rice, stonefruit, walnut/apple, or sorghum.

Table 27
Acreages of Various Crops for CDD: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	140	115	146	281	526	861	34	171	151	812	416	416
Misc.	0	0	0	0	228	0	0	0	0	0	0	0
Cotton	669	318	1,604	1,998	1,206	1,964	2,453	1,671	2,408	2,544	2,595	2,595
Alfalfa	1,003	557	606	143	278	218	92	1,009	878	573	330	330
Wheat	0	0	0	0	0	0	0	0	0	0	0	0
Melons	490	367	346	1,256	677	515	1,057	514	53	257	525	525
Process Tom.	218	460	104	0	0	0	0	74	114	60	280	280
Sugar Beets	776	649	692	80	0	200	108	69	149	60	80	80
Barley	153	0	0	0	293	0	0	0	0	0	0	0
Beans	0	0	0	0	0	0	0	44	0	0	0	0
Seed Alf.	0	0	0	0	0	0	0	0	0	0	0	0
Rice	0	0	0	0	0	0	0	0	0	0	0	0
Corn	279	902	260	0	0	0	0	90	0	0	80	80
Vegetable	30	390	0	0	550	0	14	0	0	0	0	0
Pasture	0	0	0	0	0	0	0	111	0	0	0	0
Stonefruit	0	0	0	0	0	0	0	0	0	0	0	0
Walnut/Apple	0	0	0	0	0	0	0	0	0	0	0	0
Sorghum	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3,618	3,643	3,612	3,477	3,232	2,897	3,724	3,582	3,602	3,494	3,890	3,890

FIREBAUGH CANAL WATER DISTRICT: IRRIGATED ACREAGE

Table 28 is a summary of the acreages of the various crops for the years studied. Acreage data is recorded by the district based on a calendar year format (January through December). This may cause some differences in the irrigated acreage values for crops grown and irrigated during the October through December time frame. However, the differences would be small in the accounting of the acreage. The reported acreage for major crops such as cotton are not affected by the different time frames. There was no reported acreage for the following crops; barley, beans, seed alfalfa, pasture, stonefruit. FCWD accounts for cover crops grown in the district. The acreage for cover crops was placed in the sorghum category to account for the water use.

Table 28
Acreages of Various Crops for FCWD: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	0	0	0	0	0	0	0	0	0	0	0	0
Misc.	0	0	0	0	0	0	0	0	0	0	0	0
Cotton	10,314	9,536	4,989	11,671	10,699	7,371	8,983	11,851	10,112	11,074	13,779	13,387
Alfalfa	1,611	522	935	964	992	1,218	1,692	1,834	2,119	2,298	2,550	2,600
Wheat	3,425	3,921	3,481	3,823	2,941	3,587	3,083	2,311	3,969	3,347	2,760	4,448
Melons	1,336	0	0	0	942	1,269	1,378	1,607	1,953	3,075	2,638	1,833
Process Tom.	558	0	0	0	0	0	0	710	968	1,594	1,534	1,336
Sugar Beets	2,119	1,951	1,674	1,459	2,759	2,823	3,463	2,499	3,115	2,564	832	168
Barley	0	0	0	0	0	0	0	0	0	0	0	0
Beans	0	0	0	0	0	0	0	0	0	0	0	0
Seed Alf.	0	0	0	0	0	0	0	0	0	0	0	0
Rice	1,101	1,946	3,057	1,691	649	1,240	1,143	1,287	601	302	88	111
Corn	141	125	157	0	0	1,269	0	0	0	0	0	0
Vegetable	793	2,208	1,763	1,083	749	811	565	66	515	303	312	353
Pasture	0	0	0	0	0	0	0	0	0	0	0	0
Stonefruit	0	0	0	0	0	0	0	0	0	0	0	0
Walnut/Apple	22	0	0	0	0	0	40	40	40	40	40	40
Sorghum	517	35	728	0	0	237	634	1,077	1,354	861	145	618
TOTAL	21,938	20,244	16,784	20,691	19,731	19,825	20,981	23,282	24,746	25,458	24,678	24,894

PACHECO WATER DISTRICT: IRRIGATED ACREAGE

Table 29 is a summary of the acreages of the various crops for the years studied. Acreage data is recorded by the district based on a water year format (October through September). There was no reported acreage for the following crops; sugar beets, rice, pasture, walnut/apple, or sorghum.

Table 29
Acreages of Various Crops for PWD: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	0	0	714	622	1,120	720	802	321	739	0	0	0
Misc.	0	0	0	0	0	207	440	140	243	0	0	0
Cotton	2,663	1,727	2,271	2,271	2,263	2,076	2,194	2,320	2,080	2,011	2,138	2,373
Alfalfa	0	0	0	165	162	160	320	160	178	104	487	267
Wheat	734	271	60	60	0	0	20	139	257	370	0	0
Melons	37	0	0	0	675	1,057	823	966	516	1,363	747	423
Process Tom.	0	0	0	0	0	0	0	311	210	318	472	395
Sugar Beets	0	0	0	0	0	0	0	0	0	0	0	0
Barley	189	0	0	0	0	0	0	143	127	7	0	0
Beans	153	517	702	702	0	0	0	0	37	0	110	127
Seed Alf.	234	1,330	0	0	0	0	0	0	0	0	0	0
Rice	0	0	0	0	0	0	0	0	0	0	0	0
Corn	0	165	165	0	0	0	0	0	0	0	0	0
Vegetable	0	0	98	98	0	0	231	0	0	81	415	120
Pasture	0	0	0	0	0	0	0	0	0	0	0	0
Stonefruit	400	400	400	400	0	0	0	0	0	0	0	0
Walnut/Apple	0	0	0	0	0	0	0	0	0	0	0	0
Sorghum	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4,410	4,410	3,696	3,696	3,100	3,500	4,028	4,179	3,648	4,254	4,369	3,705

PANOCHE DRAINAGE DISTRICT: IRRIGATED ACREAGE

Table 30 is a summary of the acreages of the various crops for the years studied. Acreage data is recorded by the district based on a water year format (October through September). There was no reported acreage for rice in the district. Note the signicant increase in fallow acreage in the 1991 and 1992 drought years. Note the significant irrigated acreage decrease in 1982.

Table 30
Acreage's of Various Crops for Panoche DD: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	1,165	1,218	4,703	869	869	1,468	798	852	1,029	4,235	7,916	8,566
Misc.	0	0	0	0	188	0	0	277	0	0	0	809
Cotton	18,036	10,282	13,529	17,057	15,331	14,924	14,895	18,560	15,239	14,601	13,056	12,477
Alfalfa	1,454	550	872	1,543	1,543	2,464	2,439	2,853	2,999	3,548	2,712	2,867
Wheat	4,419	1,059	2,524	3,593	2,823	2,115	3,622	837	3,451	1,825	0	298
Melons	2,712	1,552	2,507	819	3,984	2,215	1,193	1,504	3,282	3,485	1,966	2,238
Process Tom.	1,927	2,077	4,440	3,804	3,804	4,283	2,550	5,478	5,401	4,731	5,938	3,710
Sugar Beets	200	380	977	826	1,027	719	1,528	219	220	171	0	0
Barley	1,433	468	130	230	230	926	130	0	0	0	0	0
Beans	551	1,091	1,410	1,689	1,339	2,285	302	0	2,712	2,468	2,730	2,633
Seed Alf.	232	144	55	0	0	300	300	155	0	0	0	0
Rice	0	0	266	0	0	0	0	0	0	0	0	0
Corn	296	0	889	150	150	949	2,576	545	699	189	240	609
Vegetable	1,847	959	1,402	554	1,017	335	2,074	1,935	1,188	285	1,056	1,499
Pasture	111	111	111	0	680	45	0	1,122	26	0	0	0
Stonefruit	301	301	301	301	301	317	273	58	217	117	35	226
Walnut/Apple	0	0	0	32	32	250	253	252	252	379	393	376
Sorghum	632	1,012	290	156	926	1,026	73	0	0	0	0	0
TOTAL	34,151	19,986	29,703	30,754	33,375	33,153	32,208	33,795	35,686	31,799	28,126	27,742

STUDY AREA: IRRIGATED ACREAGE

Table 31 is a summary of the acreages of the various crops for the years studied for all six of the districts. Acreage data is recorded by the district based on a water year format (October through September).Note the signicant increase in fallow acreage in the 1991 and 1992 drought years.

Table 31
Acreage's of Various Crops for Entire Study Area: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	1,466	1,828	9,514	2,028	3,178	4,632	3,439	2,021	2,429	5,846	11,792	13,584
Misc.	290	300	0	140	566	347	515	417	390	0	50	957
Cotton	38,400	28,195	25,477	38,951	35,211	31,997	33,783	40,139	36,035	36,089	37,231	34,822
Alfalfa	4,356	1,917	2,861	3,263	3,125	4,207	4,883	6,341	6,725	7,074	6,865	6,848
Wheat	10,015	6,791	7,291	8,767	7,820	7,167	8,810	4,766	8,707	7,046	3,064	5,233
Melons	4,629	2,428	3,357	2,429	7,319	5,726	5,663	6,172	7,129	9,111	6,074	5,528
Process Tom.	2,923	2,537	4,844	3,954	4,554	5,033	3,000	7,253	7,533	7,553	8,886	6,801
Sugar Beets	3,859	4,044	4,407	4,484	6,506	5,652	5,955	4,703	4,879	3,901	1,775	1,030
Barley	2,378	1,265	436	476	948	1,039	184	293	168	299	319	351
Beans	1,327	1,648	2,857	2,691	1,339	2,305	302	219	2,749	2,468	2,840	2,760
Seed Alf.	1,096	2,034	490	560	630	1,005	1,330	860	694	585	456	550
Rice	1,641	2,486	3,863	2,231	1,091	2,279	2,595	2,334	1,134	1,022	881	741
Corn	757	1,233	1,512	191	150	2,306	2,706	635	699	387	320	761
Vegetable	2,670	3,557	3,263	1,735	2,316	1,146	2,884	2,001	1,703	669	1,783	1,972
Pasture	111	111	111	0	680	45	0	1,233	26	0	0	0
Stonefruit	701	701	701	701	301	317	273	58	217	117	35	226
Walnut/Apple	22	0	0	32	32	250	293	292	292	419	433	416
Sorghum	1,149	1,047	1,018	156	926	1,263	707	1,077	1,354	861	145	618
TOTAL	76,325	60,294	62,488	70,761	73,514	72,084	73,883	78,793	80,434	77,601	71,157	69,614

STEP 5: Crop Water Use

Calculate crop water use

The estimate of the crop water use is determine by multiplying the ETc of the crops by the irrigated acreage for the different districts. The previous studies incorporated an estimate of the shallow ground water upflux component from water sources outside of the district. This was not used for this study. It was felt that uncertainties in the estimates of lateral subsurface flows did not justify the estimate of a nearly insignificant value. For example, inorder to determine the crop water use for Broadview Water District in 1981; multiply the total ETc for each crop (last column) from **Table 13** by the acreage for 1981 in Broadview (second column) listed in **Table 25**. Tables 13 through 24 are used for the ETc of the crops. Tables 25 through 30 are used for the irrigated acreage of each of the districts.

Table 32 is a summary of the crop water use for the Broadview Water District. Some of the values may be different from other reports do to combining acreages, conservative estimates of ETc, or other factors. **Table 33** through **Table 37** reflect the crop water use for the other districts. **Table 38** is the summary table of the crop water use for the study area.

Table 32
Crop Water Use (in AF) for Broadview Water District: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	285	298	1,178	219	215	345	197	205	250	1,029	1,904	2,060
Misc.	0	0	0	0	220	0	0	311	0	0	0	914
Cotton	35,527	20,253	28,840	34,704	30,070	28,372	29,001	34,661	30,783	28,516	24,951	24,232
Alfalfa	4,925	1,863	3,056	5,448	5,259	8,029	8,371	9,375	10,146	11,928	8,922	9,598
Wheat	5,376	1,288	2,747	4,751	3,564	2,468	4,561	1,093	4,169	2,220	0	339
Melons	2,728	1,561	2,786	864	4,037	2,129	1,197	1,380	3,365	3,444	1,923	2,153
Process Tom.	3,815	4,112	9,533	7,728	7,515	8,176	5,006	10,213	11,055	9,268	11,416	7,145
Sugar Beets	558	1,060	2,798	2,313	2,878	1,926	4,240	609	602	475	0	0
Barley	1,560	510	124	271	261	966	147	0	0	0	0	0
Beans	841	1,665	2,393	2,717	2,037	3,324	457	0	4,240	3,675	4,033	3,865
Seed Alf.	410	255	98	0	0	508	541	268	0	0	0	0
Rice	0	0	871	0	0	0	0	0	0	0	0	0
Corn	601	0	1,964	314	303	1,856	5,164	1,043	1,462	379	473	1,209
Vegetable	2,102	1,091	1,547	697	1,193	369	2,482	2,175	1,358	319	1,083	1,693
Pasture	407	407	417	0	2,523	159	0	4,043	95	0	0	0
Stonefruit	981	981	1,032	1,029	984	998	898	181	711	378	110	730
Walnut/Apple	0	0	0	112	107	802	848	801	850	1,249	1,254	1,234
Sorghum	1,104	1,767	548	282	1,604	1,726	126	0	0	0	0	0
TOTAL	61,219	37,112	59,932	61,448	62,771	62,151	63,235	66,358	69,086	62,882	56,069	55,172

Table 33
Crop Water Use (in AF) for CCID (Camp 13): 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	39	39	40	41	79	171	167	35	14	0	0	0
Misc.	0	0	0	0	0	0	0	0	0	0	0	0
Cotton	2,067	2,067	2,237	2,135	3,285	2,720	2,993	2,594	3,125	2,818	3,507	3,366
Alfalfa	975	975	1,009	1,017	0	0	1,167	1,594	1,864	1,852	2,451	2,625
Wheat	476	476	426	517	1,355	580	1,165	1,032	389	731	0	554
Melons	55	55	60	57	254	0	132	42	47	116	0	59
Process Tom.	0	0	0	0	0	0	0	0	0	0	0	0
Sugar Beets	2,131	2,131	2,188	2,140	5,521	3,977	1,543	4,068	3,407	2,239	2,442	2,158
Barley	61	61	53	66	0	0	0	0	0	0	320	353
Beans	0	0	0	0	0	0	0	0	0	0	0	0
Seed Alf.	0	0	0	0	0	0	0	0	0	0	0	0
Rice	1,655	1,655	1,767	1,726	1,365	3,077	4,486	3,006	1,119	2,179	2,326	1,899
Corn	83	83	90	85	0	172	261	0	0	397	0	143
Vegetable	0	0	0	0	0	0	0	0	0	0	0	0
Pasture	0	0	0	0	0	0	0	0	0	0	0	0
Stonefruit	0	0	0	0	0	0	0	0	0	0	0	0
Walnut/Apple	0	0	0	0	0	0	0	0	0	0	0	0
Sorghum	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	7,541	7,541	7,870	7,783	11,859	10,698	11,914	12,370	9,964	10,334	11,046	11,155

Table 34
Crop Water Use (in AF) for Charleston Drainage District: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	34	28	37	71	130	202	8	41	37	197	100	100
Misc.	0	0	0	0	267	0	0	0	0	0	0	0
Cotton	1,318	626	3,419	4,065	2,365	3,734	4,776	3,121	4,864	4,969	4,959	5,040
Alfalfa	3,397	1,887	2,124	505	947	710	316	3,316	2,970	1,926	1,086	1,105
Wheat	0	0	0	0	0	0	0	0	0	0	0	0
Melons	493	369	385	1,325	686	495	1,061	472	54	254	514	505
Process Tom.	432	911	223	0	0	0	0	138	233	118	538	539
Sugar Beets	2,164	1,810	1,982	224	0	536	300	192	408	167	226	221
Barley	167	0	0	0	332	0	0	0	0	0	0	0
Beans	0	0	0	0	0	0	0	62	0	0	0	0
Seed Alf.	0	0	0	0	0	0	0	0	0	0	0	0
Rice	0	0	0	0	0	0	0	0	0	0	0	0
Corn	566	1,830	574	0	0	0	0	172	0	0	158	159
Vegetable	34	444	0	0	645	0	17	0	0	0	0	0
Pasture	0	0	0	0	0	0	0	400	0	0	0	0
Stonefruit	0	0	0	0	0	0	0	0	0	0	0	0
Walnut/Apple	0	0	0	0	0	0	0	0	0	0	0	0
Sorghum	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	8,604	7,905	8,744	6,190	5,374	5,677	6,477	7,913	8,567	7,630	7,581	7,669

Table 35
Crop Water Use (in AF) for Firebaugh Canal Water District: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	0	0	0	0	0	0	0	0	0	0	0	0
Misc.	0	0	0	0	0	0	0	0	0	0	0	0
Cotton	20,316	18,784	10,635	23,746	20,985	14,013	17,490	22,132	20,426	21,628	26,333	26,000
Alfalfa	5,457	1,768	3,277	3,403	3,381	3,969	5,807	6,026	7,169	7,726	8,389	8,704
Wheat	4,166	4,770	3,789	5,055	3,713	4,186	3,882	3,018	4,795	4,072	3,082	5,057
Melons	1,344	0	0	0	955	1,220	1,383	1,475	2,003	3,039	2,581	1,764
Process Tom.	1,105	0	0	0	0	0	0	1,324	1,981	3,123	2,949	2,573
Sugar Beets	5,908	5,440	4,794	4,085	7,732	7,560	9,609	6,953	8,524	7,124	2,354	464
Barley	0	0	0	0	0	0	0	0	0	0	0	0
Beans	0	0	0	0	0	0	0	0	0	0	0	0
Seed Alf.	0	0	0	0	0	0	0	0	0	0	0	0
Rice	3,377	5,966	10,006	5,405	2,004	3,673	3,531	3,695	1,894	914	258	335
Corn	286	254	347	0	0	2,482	0	0	0	0	0	0
Vegetable	903	2,513	1,945	1,362	878	892	676	74	589	339	320	399
Pasture	0	0	0	0	0	0	0	0	0	0	0	0
Stonefruit	0	0	0	0	0	0	0	0	0	0	0	0
Walnut/Apple	73	0	0	0	0	0	134	127	135	132	128	131
Sorghum	903	61	1,377	0	0	399	1,091	1,795	2,429	1,490	245	1,065
TOTAL	43,838	39,555	36,169	43,057	39,648	38,393	43,604	46,619	49,943	49,586	46,639	46,490

Table 36
Crop Water Use (in AF) for Pacheco Water District: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	0	0	179	157	277	169	198	77	180	0	0	0
Misc.	0	0	0	0	0	228	527	157	278	0	0	0
Cotton	5,245	3,402	4,841	4,621	4,439	3,947	4,272	4,333	4,202	4,062	4,176	4,609
Alfalfa	0	0	0	583	552	521	1,098	526	602	352	1,637	894
Wheat	893	330	65	79	0	0	25	182	310	447	0	0
Melons	37	0	0	0	684	1,016	826	887	529	1,398	738	407
Process Tom.	0	0	0	0	0	0	0	580	430	651	925	761
Sugar Beets	0	0	0	0	0	0	0	0	0	0	0	0
Barley	206	0	0	0	0	0	0	169	137	8	0	0
Beans	234	789	1,192	1,129	0	0	0	0	58	0	164	186
Seed Alf.	414	2,351	0	0	0	0	0	0	0	0	0	0
Rice	0	0	0	0	0	0	0	0	0	0	0	0
Corn	0	335	365	0	0	0	0	0	0	0	0	0
Vegetable	0	0	108	123	0	0	276	0	0	93	464	136
Pasture	0	0	0	0	0	0	0	0	0	0	0	0
Stonefruit	1,304	1,304	1,371	1,367	0	0	0	0	0	0	0	0
Walnut/Apple	0	0	0	0	0	0	0	0	0	0	0	0
Sorghum	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	8,332	8,510	8,121	8,059	5,952	5,881	7,222	6,910	6,725	7,010	8,104	6,992

Table 37
Crop Water Use (in AF) for Panoche Drainage District: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	285	298	1,178	219	215	345	197	205	250	1,029	1,904	2,060
Misc.	0	0	0	0	220	0	0	311	0	0	0	914
Cotton	35,527	20,253	28,840	34,704	30,070	28,372	29,001	34,661	30,783	28,516	24,951	24,232
Alfalfa	4,925	1,863	3,056	5,448	5,259	8,029	8,371	9,375	10,146	11,928	8,922	9,598
Wheat	5,376	1,288	2,747	4,751	3,564	2,468	4,561	1,093	4,169	2,220	0	339
Melons	2,728	1,561	2,786	864	4,037	2,129	1,197	1,380	3,365	3,444	1,923	2,153
Process Tom.	3,815	4,112	9,533	7,728	7,515	8,176	5,006	10,213	11,055	9,268	11,416	7,145
Sugar Beets	558	1,060	2,798	2,313	2,878	1,926	4,240	609	602	475	0	0
Barley	1,560	510	124	271	261	966	147	0	0	0	0	0
Beans	841	1,665	2,393	2,717	2,037	3,324	457	0	4,240	3,675	4,033	3,865
Seed Alf.	410	255	98	0	0	508	541	268	0	0	0	0
Rice	0	0	871	0	0	0	0	0	0	0	0	0
Corn	601	0	1,964	314	303	1,856	5,164	1,043	1,462	379	473	1,209
Vegetable	2,102	1,091	1,547	697	1,193	369	2,482	2,175	1,358	319	1,083	1,693
Pasture	407	407	417	0	2,523	159	0	4,043	95	0	0	0
Stonefruit	981	981	1,032	1,029	984	998	898	181	711	378	110	730
Walnut/Apple	0	0	0	112	107	802	848	801	850	1,249	1,254	1,234
Sorghum	1,104	1,767	548	282	1,604	1,726	126	0	0	0	0	0
TOTAL	61,219	37,112	59,932	61,448	62,771	62,151	63,235	66,358	69,086	62,882	56,069	55,172

Table 38
Crop Water Use (in AF) for Entire Study Area: 1981-1992

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Fallow	359	447	2,382	512	786	1,088	850	485	590	1,421	2,836	3,268
Misc.	330	341	0	176	664	382	616	469	446	0	51	1,081
Cotton	75,639	55,538	54,310	79,250	69,061	60,829	65,776	74,960	72,791	70,618	71,241	67,630
Alfalfa	14,754	6,493	10,026	11,520	10,650	13,708	16,760	20,836	22,751	23,785	22,621	22,926
Wheat	12,183	8,261	7,936	11,592	9,873	8,363	11,094	6,224	10,518	8,568	3,421	5,949
Melons	4,657	2,443	3,732	2,563	7,417	5,503	5,683	5,665	7,310	9,054	5,950	5,319
Process Tom.	5,788	5,023	10,400	8,033	8,997	9,607	5,890	13,522	15,419	14,825	17,101	13,097
Sugar Beets	10,760	11,277	12,621	12,556	18,233	15,136	16,524	13,085	13,350	10,839	5,022	2,843
Barley	2,589	1,377	415	561	1,075	1,084	208	347	181	327	320	353
Beans	2,025	2,515	4,850	4,329	2,037	3,353	457	309	4,298	3,675	4,197	4,051
Seed Alf.	1,937	3,595	876	1,064	1,138	1,701	2,400	1,489	1,237	1,019	756	937
Rice	5,032	7,621	12,644	7,131	3,370	6,750	8,018	6,701	3,573	3,094	2,584	2,233
Corn	1,535	2,501	3,340	399	303	4,511	5,424	1,215	1,462	777	630	1,511
Vegetable	3,039	4,048	3,600	2,182	2,716	1,261	3,451	2,249	1,947	750	1,867	2,227
Pasture	407	407	417	0	2,523	159	0	4,442	95	0	0	0
Stonefruit	2,285	2,285	2,403	2,396	984	998	898	181	711	378	110	730
Walnut/Apple	73	0	0	112	107	802	982	928	985	1,381	1,381	1,365
Sorghum	2,007	1,829	1,925	282	1,604	2,125	1,216	1,795	2,429	1,490	245	1,065
TOTAL	145,399	116,002	131,877	144,657	141,539	137,360	146,246	154,904	160,093	152,001	140,335	136,584

STEP 6: Effective Rainfall

Calculation of the effective rainfall.

The estimate of the effective rainfall was made by estimating the amount of water that is available for crop use or aids in the leaching of salts. There are numerous approaches to determine the effective precipitation. This report uses an estimate based on multiplying the total rainfall occuring during October through March by 50%. This value is based on published estimates by DWR. Based on discussions with irrigation engineers in the area, this estimate may slightly overestimate the amount of rain that is effective. The timing of the events is critical. A grower has to be absolutely ready to take advantage of a rain event. Theoretical calculations of the amount of rain that is effective do not apply to the grower who was not able to prepare the furrows for planting. A pre-irrigation event will still be required to ensure adequate moisture for germination.

Precipitation events in the time period between harvest and planting play a large part in determining the amount of irrigation water needed for pre-plant irrigation. The amount of the total rainfall that actually infiltrates into the soil, and is available for use by the plant must be estimated and will vary widely depending on geographic, soil, and surface conditions. Rainfall for each of the districts was assumed to be equal to values recorded with a rain gage placed at Mendota Dam.

Effective rainfall is defined as that rain which infiltrates and either;

- stays in the effective rootzone of the crop, available for ETc
- is effective in satisfying maintenance (net) or reclamation leaching.

Monthly rainfall records were obtained for the weather station at Mendota Dam and are shown in **Table 39**. Rainfall records from CIMIS Station #7 were not used due to poor site conditions.

Table 39
Gross Monthly Rainfall (in Inches) Reported at Mendota Dam

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Average
Oct	0.00	0.37	0.60	0.59	0.55	0.49	0.00	0.83	0.00	0.64	0.04	0.24	0.36
Nov	0.11	2.25	1.91	1.14	1.05	3.11	0.00	0.59	0.67	0.31	0.27	0.07	0.96
Dec	0.30	0.27	1.03	1.54	2.67	0.97	0.35	1.23	2.13	0.00	0.41	0.87	0.98
Jan	1.61	0.70	3.53	0.10	0.60	0.11	1.14	1.18	0.29	2.05	0.07	1.45	1.07
Feb	0.78	0.66	1.80	1.38	0.09	2.92	1.90	0.46	1.15	0.92	1.01	2.46	1.29
Mar	3.57	2.77	4.57	0.49	0.62	2.44	2.15	0.18	0.88	0.45	3.12	2.24	1.96
Apr	1.32	1.81	0.84	0.03	0.14	0.51	0.00	1.13	0.13	0.39	0.11	0.00	0.53
May	0.00	0.00	0.45	0.00	0.00	0.12	0.12	0.29	0.09	1.20	0.00	0.05	0.19
Jun	0.00	0.12	0.00	0.08	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Sep	0.00	0.78	0.77	0.00	0.00	0.36	0.00	0.00	1.36	0.09	0.00	0.00	0.28
Oct-Mar Only	6.37	7.02	13.44	5.24	5.58	10.04	5.54	4.47	5.12	4.37	4.92	7.33	
Totals	7.69	9.73	15.50	5.35	5.77	11.03	5.66	5.89	6.70	6.05	5.05	7.45	7.66

To determine the effective rainfall, the annual rainfall values were multiplied by the cropped acreage (excluding fallow land) and multiplied by the effective rain factor (50%). **Table 40** summarizes the amount of rainfall that was assumed to be effective.

Table 40
Effective Rainfall (in AF)

District	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Avg.
BWD	2,395	2,582	3,086	1,956	2,015	3,417	1,817	1,627	1,853	1,486	1,135	1,369	2,062
CCID-13	845	931	1,783	695	1,258	1,899	1,171	972	867	808	934	1,497	1,138
CDD	960	1,066	2,023	759	751	1,212	860	667	768	636	797	1,188	974
FCWD	5,823	5,921	9,399	4,518	4,587	8,293	4,843	4,336	5,279	4,635	5,059	7,603	5,858
PoWD	1,170	1,290	2,070	807	721	1,464	930	778	778	775	896	1,132	1,068
PDD	9,064	5,846	16,634	6,715	7,760	13,869	7,435	6,294	7,613	5,790	5,766	8,473	8,438
TOTAL	20,258	17,636	34,993	15,450	17,092	30,155	17,055	14,675	17,159	14,130	14,587	21,261	19,538

Note the wet years in 1983 and 1986. These years tend to show up as poor irrigation efficiencies since so much rain water is accounted for as effective rain. This basically means that the rains were efficient and not the irrigations which may not be true. Growers can not "plan" on receiving adequate rain. Therefore, they irrigate to maximize economic gain and ensure adequate germination.

STEP 7: Water Delivered

Report of the water delivered.

The water delivery records proved to be the most difficult of the data collection tasks. The original stuies had requested information in a calendar year format based on deliveries to the district. None of the districts had this information readily available for all of the years in this format. Water delivery records from the DMC and SLC did not correlate to the district records. Most districts tracked water deliveries on different time lines. The results of the data collection effort represent numerous references. Since most of the districts do not track water in the format requested, values were obtained from personal communications rather than using published reports. The following table is an estimate of the actual water delivered to the district or water supplied from another source outside of the study boundaries (such as a deep well).

Table 41
Annual Water Delivered (in AF)

District	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
BWD	28,932	25,211	15,690	31,911	28,240	24,628	23,308	25,891	25,200	20,582	12,902	9,086
CCID	15,251	15,251	15,251	15,251	18,914	15,072	16,255	16,738	11,049	13,081	16,351	14,546
CDD	14,030	11,973	11,591	13,691	12,119	10,264	13,891	14,428	12,263	11,127	10,218	9,630
FCWD	75,645	66,132	47,400	80,268	75,432	62,966	79,545	75,106	70,326	63,903	57,141	59,569
PoWD	12,653	9,763	9,751	10,775	9,000	7,770	9,756	10,217	13,063	11,569	11,572	8,107
PDD	97,344	89,155	75,306	109,511	98,241	92,487	98,119	97,196	91,300	81,258	69,706	63,416
TOTAL	241,675	215,562	173,087	259,342	239,864	211,467	238,800	237,425	221,310	199,661	175,907	162,676

Broadview Water District water supply data were from the district. They have good delivery records in a monthly format. The records are primarily delivered water from the USBR.

CCID-Camp 13 water supply data was from the district from water delivery "tags." A conveyance loss (6.7%) needed to be added to the water delivered values for this district subarea since the only records were for water delivered to the grower.

Charleston Drainage District water supply data was from the San Luis Water District which supplies water to this drainage subarea. In 1991 and 1992, there was a significant "shortage" of water that could not be explained. Rather than have irrigation efficiencies that reflected unrealistic values, an estimate of the water made available was made to account for the acreage of crops grown. An additional 4,188 AF and 2,804 AF was added to 1991 and 1992, respectively to account for the irrigated acreage.

Firebaugh Canal Water District water supply data were taken from two sources which differed considerably. The USBR's DMC supply water dumps into the Mendota Pool where it is delivered to four districts (FCWD, CCID, CCC, and SLCC) under a single contract. The division of water among the four districts is an internal agreement and the USBR only checks FCWD's main intake weir periodically. FCWD's manager states that some reported FCWD water deliveries account for water twice. There are some tailwater systems in the district and field tailwater will go back into the district's supply for use by other farmers. Also, although significant only since 1990, some tilewater has been recycled, if water quality is sufficiently good.

Pacheco Water District water supply data were from two sources for water supplies which differed considerably. PoWD's supply comes from a Federal Contract and an agreement with CCID. PoWD's records were used, except in 1988 (incomplete data set). Water deliveries as reported by the USBR were used for 1988. The water supply for 1990 through 1992 came from PoWD directly (Dermer, 1991). From 1985 to 1988, PoWD was required to release portions of the delivered water directly into the Grassland Water District system for dilution. The amounts released were 2,337 AF in 1985, 3,772 AF in 1986, 3,231 in 1987, and 655 in 1988.

Panoche Drainage District water supply was from the district records. A sub-task was the determination of the volume of pumped irrigation water from private irrigation wells to individual farms in the Panoche Water District. Contact was made with most of the growers who maintain and operate about 42 wells in the Panoche area. Rick Shoneman of the ARS in Fresno met individually with the growers in the field. Growers were asked to estimate the amount of groundwater pumping. In most cases, the wells do not have meters and the data was roughly estimated. The irrigation efficiency calculations include an estimate for the groundwater pumping. However, the estimates of the private pumping did not appear to account for all of the water required to irrigate the crops grown. In 1991 and 1992, there was a significant "shortage" of water that could not be explained. Rather than have irrigation efficiencies that reflected unrealistic values, an estimate of the water made available was made to account for the acreage of crops grown. An additional 26,387 AF and 25,865 AF was added to 1991 and 1992, respectively to account for the irrigated acreage from groundwater pumping. These values were determined by evaluating a minimum reasonable water dellivered to meet ETc. In 1990 an estimated 3,000 AF was pumped. Panoche is the only district with reported pumped water volumes.

STEP 8: Leaching Required

Calculation of the amount of water required for leaching of salts.

Irrigation water quality measurements were obtained from the districts at the location they felt was most representative of the average quality of the water delivered. Where no yearly ECw values were available (Pacheco and Panoche) the values were estimates supplied by the districts. ECw values for Firebaugh and Charleston for 1982 and 1983 were estimated. The leaching requirement used in finding the PIE was based on maintaining a maximum salt level of 2.5 dS/m in the rootzone. It was assumed that all leaching was done during pre-plant irrigations, and that the necessary leaching to maintain maximum salt levels was done yearly. In actual practice, it is possible to defer leaching for more salt tolerant crops, and irrigation water earmarked for beneficial use as leaching may be actually used for other purposes within the district. In all likelihood, during years when there is less water delivered to the district, much of the leaching is deferred, to be taken care of during years with high rainfall or more available water. This appears in the data for 1990-1992, where the water applied is less than the potential beneficial water use. In 1993, it is expected that the districts would increase the water applied during the pre-plant time frame to account for unsatisfied leaching requirements from 1990-1992.

Table 41 summarizes the water quality values for the districts. Note the high values in 1981 and 1982 for Broadview Water District. These values reflect the water quality of 100% recycling. The remaining years are also high which reflect a large percentage of recycling occuring within the district. They did not have an outlet for the drainage water until 1983. Pacheco Water District also has high values. This reflects a higher amount of recycling within the district. Pacheco reports that alsmost all of the tailwater within the district is recycled and about 50% of the tile water. Recycling of all of the tailwater is feasible for all of the districts. However, recycling all of the tile water leads to very high water salinities of the delivered water. The expected salinities for

100% tile water recycling could be as high as 3 dS/m. 50% tilewater recycling could result in salinities of about 1.5 dS/m. This would have a negative impact on those districts currently discharging the tile water.

Table 42
Water Quality of District Delivered Water (in dS/m)

District	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
BWD	3.21	2.89	0.89	0.74	0.65	0.67	0.56	0.87	0.75	1.06	1.25	1.00
CCID-13	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
FCWD	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
CDD	0.54	0.54	0.54	0.38	0.50	0.39	0.59	0.62	0.53	0.60	0.59	0.62
PoWD	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.54	1.54	1.54	1.54
PDD	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.70	0.70
Ave.	1.09	1.03	0.70	0.65	0.65	0.64	0.65	0.71	0.74	0.80	0.86	0.82

The calculation for the water required for leaching is the product of the delivered water times the fraction required for leaching. The fraction of water required for leaching is from the equation:

$$LR = \frac{ECw}{(5 \times ECe) - ECw}$$

Where; LR = fraction of water required for leaching

ECw = Salinity of the delivered water in dS/m

ECe = Threshold soil salinity (2.5 dS/m)

Table 43 is a summary of the water required for leaching for the districts. Note the fluctuating amounts in some of the districts caused by a high amount of recycling of tile water.

Table 43
Water Required for Leaching (in AF)

District	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Avg.
BWD	9,997	7,582	1,203	2,008	1,549	1,395	1,093	1,937	1,609	1,907	1,434	790	2,709
CCID-13	689	689	689	689	854	681	734	756	499	591	738	657	689
CDD	633	541	523	429	505	331	688	753	543	561	506	503	543
FCWD	3,415	2,986	2,140	3,624	3,406	2,843	3,592	3,391	3,175	2,885	2,580	2,690	3,061
PoWD	1,282	989	988	1,092	912	787	988	1,035	1,835	1,626	1,626	1,139	1,192
PDD	4,395	4,025	3,400	4,944	4,436	4,176	4,430	4,388	4,122	3,669	4,135	3,762	4,157
Total	20,412	16,811	8,943	12,786	11,661	10,212	11,525	12,260	11,783	11,238	11,019	9,540	12,349

STEP 9: District Irrigation Efficiency

Calculation of the district irrigation efficiency.

Water rights are generally based on some combined measure of the need for beneficial use and reasonableness of use. Water allocation decisions require an opinion on how much of the non-beneficially used irrigation water can be classified as "reasonable" use. All non-beneficial uses decrease the Irrigation Efficiency (IE) below its maximum possible value of 100%. Irrigation Efficiency is defined as:

$$IE = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied}} \times 100$$

Beneficially used irrigation water has traditionally included the following:

- Crop transpiration; the major component.

- Water needed for leaching requirement (LR), which is typically 3-10% of the gross applied.

- Climate control, such as evaporative cooling or frost protection with sprinklers (not accounted for in this study).

- Use of water for germination of weeds (limited to 1 inch or so per year), so that the weeds can be killed either mechanically or with herbicides (not accounted for in this study).

- Minimal amounts needed for cultural practices such as packing the soil for harvest of some crops or "freshening" of some vegetables before harvest (not accounted for in this study).

These beneficial uses all occur at the farm level. On the district level, less contaminated water which is required for blending of drainage water in order to meet drainage discharge standards (ie., San Joaquin River water quality standards) may also be considered as "beneficial use" since it is necessary to maintain aquatic habitat standards.

Non-beneficial uses of irrigation water on-farm include:

- Canal and ditch seepage and evaporation.

- Evaporation from the field, unless it offsets transpiration requirements.

- Deep percolation in excess of the leaching requirement. Causes of this deep percolation are:
    - Excess duration of irrigations.
    - Nonuniformity of irrigation water infiltration into the soil.

- Uncollected tailwater, except for the small fraction of it which contributes to a beneficial salt balance due to pickup of surface salts. Such a salt pickup is minor in areas of the San Joaquin Valley, but can be important in very hot areas with heavy soils such as the Imperial Valley.

- Spray losses from sprinklers.

Some evaporation and nonuniformity always exist with irrigations, regardless of the method. The exception regarding evaporation might be row crop drip, but during seed germination the soil surface has to be wet somehow, at which time evaporation will occur. Imprecise irrigation timing is also inevitable, due to uncertainties regarding water deliveries, evapotranspiration rates, soil intake rates, soil water depletions, and precise rooting depths.

The values are reported as District Irrigation Efficiencies. The DIE includes water lost from operational discharges and seepage losses from supply canals. The irrigation efficiency is calculated with the following equation:

$$\text{DIE} = \frac{(\text{ETc with adjustment} + \text{Leaching required for salt control} - \text{Effective Rain})}{\text{Irrigation Water Applied}} \times 100$$

Where; DIE = District Irrigation Efficiency (%)

ETc = Adjusted ETc values from Tables 13 - 25

Leaching = Water applied for leaching of salts (Table 41)

Effective Rain = Rain used by crops or for salt control (Table 39)

Table 44 summarizes the revised data. Note the low irrigation efficiency values in 1983 and 1986. These years were high rainfall amount years. Note Broadview Water District's high values in 1981 and 1982 and then decreasing in 1983 when they obtained an outlet to the San Joaquin River. The 80% efficiency represented a very high efficiency with 100% recycling of tailwater and tilewater. Since the water quality degraded to a unsatisfactory value, the 80% may well represent a maximum attainable irrigation efficiency. Note that after several years of high irrigation efficiency, the DIE drops in value significantly in Broadview. This can be partially explained by the result of leaching done in subsequent years to make up for water short years. This means that the highest values on the table may reflect levels that are not maintainable.

The trend is definitely one of increasing irrigation efficiency over the 12 years of the study. This reflects a necessary reaction by growers and districts to respond to decreasing water supplies and increasing environmental, political, and social concerns of drainage.

Table 44
District Irrigation Efficiency
ETc Approach

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Broadview	81%	81%	58%	57%	55%	51%	56%	58%	62%	73%	87%	94%
CCID	48%	48%	44%	51%	61%	63%	71%	73%	87%	77%	66%	71%
Charleston	59%	62%	62%	43%	42%	47%	45%	55%	68%	68%	71%	73%
Firebaugh	55%	55%	61%	53%	51%	52%	53%	61%	68%	75%	77%	70%
Pacheco	67%	84%	72%	77%	68%	67%	75%	70%	60%	68%	76%	86%
Panoche	58%	40%	62%	54%	61%	57%	61%	66%	72%	75%	78%	80%
Regional IE	**60%**	**53%**	**61%**	**55%**	**57%**	**56%**	**59%**	**64%**	**70%**	**75%**	**78%**	**77%**

Figure 16 is a graphical representation of the data from Table 44. The trends are quite apparent on the graph. Note the erratic numbers of some of the smaller districts. This is most likely due to potential problems in the data rather the significant data points that can be explained.

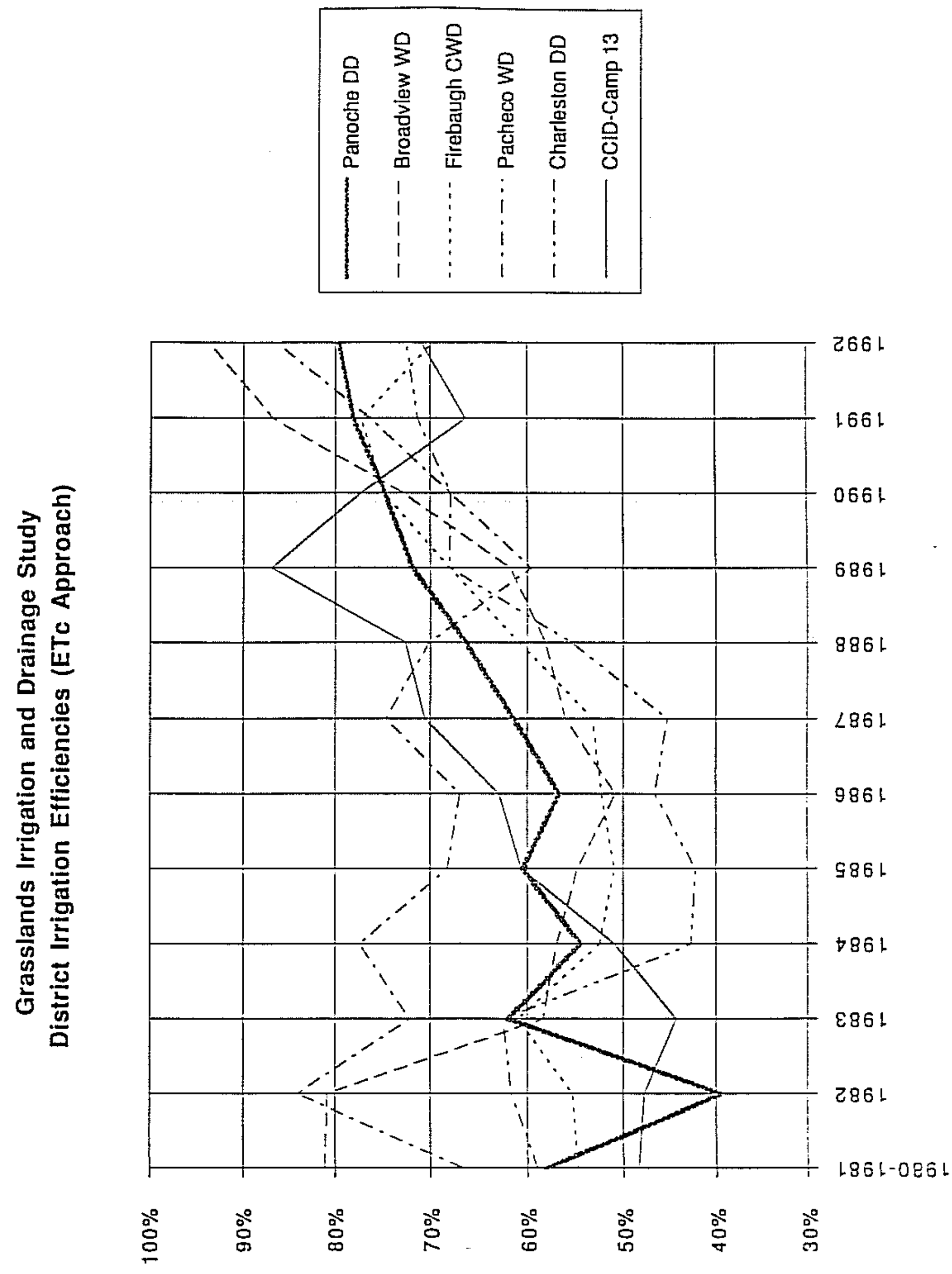

Grasslands Irrigation and Drainage Study
District Irrigation Efficiencies (ETc Approach)
Panoche DD
Broadview WD
Firebaugh CWD
Pacheco WD
Charleston DD
CCID-Camp 13
100%
90%
80%
70%
60%
50%
40%
30%
1980-1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

Figure 16

PROBLEMS WITH VERIFYING DIE ESTIMATES

Using the ETc approach to estimate the DIE has several limitations. Some of the problems are discussed below.

DIFFERENT REPORTING AREAS

One of the major problems is that the areas providing information on the acreage of the various crops grown and water supply are many times not the same area providing reported drainage. For example, PoWD also provides drainage for approximately 640 acres of land outside of it. BWD provides drainage for the FDA, which consists of BWD and 3000 acres that are within WWD.

CROP ETc

There are two major problems in calculating crop ETc:

1. There must be accurate estimates of which crops are being grown.

2. There must be accurate estimates of individual seasonal crop ETc.

The problems of calculating ETc are discussed in detail in the 1991 DIE Report (Burt et al, 1991).

WATER SUPPLY

There are at least two reasons why the estimates for water supply will be inaccurate:

1. The USBR reports that they attempt to maintain a +/- 3% accuracy in the flow meters on the DMC. (Note the effect of this inaccuracy on the comparison of estimated drainage versus Reported Drainage). Looking at PDD, the water supply is in the range of 94,000 acre-feet/year. Three percent of this would be about 2,800 acre-feet/year. PeWD drainage through measuring point PE-14 has ranged from 25,000 acre-feet to 33,700 acre-feet from 1986 to 1989. 2,800 acre-feet is from 8 to 11% of their reported drainage. Thus, due to inaccuracies in measuring the water supply alone, a drainage estimate could be in the range of +/- 10% from the reported drainage.

2. In addition, pumping from farmer-owned deep wells must be accounted for. They are rarely, if ever, metered and reported to the district.

LATERAL INFLOWS

There are two types of lateral inflows to the district that are not regulated or measured:

1. Subsurface lateral inflows are a point of contention among many of the districts in the area. Subsurface flows are said to cause a "base flow" in the tile drainage systems. That is, regardless of irrigation on the land, the tile drains will collect a certain amount of deep percolation that is moving laterally from upslope lands. BWD, in a 1985 report, estimated that 27% of their tile drainage originated on lands upslope of their district. It is also claimed that selenium and other heavy metals are carried with these inflows.

2. There may also be surface inflows to a district that will be picked up and used on an "if and when available" basis by farmers.

REPORTING PERIODS

A major problem is the number of different time periods that will be used by those reporting totals for irrigation water deliveries, drainage, tile sump flows, etc. At least three different periods are in common use:

1. There is the "water year", which generally runs from March of one year through February of the next. This coincides with the length of USBR and SWP delivery contracts.

2. There is the calendar year, from January through December.

3. There have been some reports that refer to water use during a "crop year", which was reported to run from October of one year to September of the next. The starting month of October was chosen because it usually is the start of pre-plant irrigations and/or grain planting for the next growing season.

SECTION 4

PRE-PLANT IRRIGATION EFFICIENCY

INTRODUCTION

Examination of pre-plant irrigation efficiencies for five of the Grassland Basin districts was completed in order to determine the potential for reduction of drainage water from the area during the period of time when pre-plant irrigation events occur (December through March). In theory, the time frame for the poorest irrigation efficiencies occurs during the pre-plant irrigations since irrigations are required for germination but the soil moisture deficit may not warrant the quantity of water applied. The pre-plant efficiency analysis was completed during the summer of 1993. Some of the assumptions are slightly different than the assumptions used in the DIE analysis due to the timing of the analysis. The differences are discussed later in this section.

The five districts examined were Panoche, Firebaugh, Broadview, Pacheco, and Charleston. CCID was not evaluated due to lack of monthly water delivery data. Pre-plant irrigation efficiencies were determined by calculating the potential beneficial uses of irrigation water during the time period, and comparing that to the amount of water delivered to the district on a monthly basis during the same time period.

DATA ANALYSIS

The variables involved in the examination of pre-plant irrigation efficiencies (hereafter known as PIE) are as follows:

- District monthly water delivery figures.
- Estimates of irrigation water quality and leaching requirements.
- Estimates of harvest SMD, soil type, crop root zone depths at harvest, the effects of tiling and ground water levels on SMD, and calculations of the amount of irrigation water needed to fill up the SMD prior to planting time.
- Effectiveness of post-harvest precipitation in filling SMD.

- Crop acreage.

- Crop rotation patterns.

- Distribution uniformity of the irrigation events.

- Crop ETc requirements.

Of these categories, the first four are the most significant in effecting the final PIE values. Each of the categories will be evaluated individually.

DISTRICT MONTHLY WATER DELIVERY

The monthly values given by the water districts are thought to be reasonably accurate for Panoche, Firebaugh, and Broadview. The monthly water supply values for Pacheco are numbers obtained from the Bureau and are inconsistent with yearly delivery values reported by the district. The monthly values for Charleston are also suspect, being reported numbers from the San Luis Canal and also inconsistent with yearly values reported by the district. The monthly values used in the examination do not include irrigation water from well pumping, which is thought to be significant only for Panoche Water District. Obtaining an estimate of well water pumping in Panoche would involve an audit of the PG&E records for the area and permission of the land owners to conduct such an audit, a task which proved beyond the scope of this project. Monthly water delivery values represent the water delivered to the district and do not reflect losses due to seepage, evaporation, or spillage, which can be an estimated 7-10 percent of the water delivered. Losses were not included in the calculation of the PIE since there was doubt about the actual values involved. Monthly values were obtained from the districts and from the Bureau.

ESTIMATES OF WATER QUALITY AND LEACHING REQUIREMENTS

Irrigation water quality measurements were obtained from the districts at the location they felt was most representative of the average quality of the water delivered. Where no yearly ECw values were available (Pacheco and Panoche) the values were estimates supplied by the districts. ECw values for Firebaugh and Charleston for 1982 and 1983 were estimated. The leaching requirement used in finding the PIE was based on maintaining a maximum salt level of 2.5 dS/m. It was assumed that all leaching was done during pre-plant irrigation's, and that the necessary leaching to maintain maximum salt levels was done yearly. In actual practice, it is possible to defer leaching for more salt tolerant crops, and irrigation water earmarked for beneficial use as leaching may be actually used for other purposes within the district. In all likelihood, during years when there is less water delivered to the district, much of the leaching is deferred, to be taken care of during years with high rainfall or more available water. This appears in the data for 1990-1992, where the water applied is less than the potential beneficial water use. In 1993, it was expected that the districts would increase the water applied during the pre-plant time frame to account for leaching requirements from 1990-1992. The calculated PIE does not take this into account.

ESTIMATES OF HARVEST SMD, SOIL TYPE, CROP ROOTZONE DEPTHS

In order to estimate the SMD at the time of year when pre-plant irrigation events occur, it was necessary to find the SMD at harvest time, which is usually determined by crop and harvesting requirements. Estimates were made for rootzone depths, soil characteristics, contribution from ground water (which is affected by the percent of tiled acreage), and the amount of rainfall infiltrated in the months preceding the pre-plant irrigation events. Since there was no information on site- or crop-specific water deliveries, all of the influencing factors except for crop related information had to be generalized over the water district, which can lead to inaccuracies in finding the amount of irrigation water beneficially used for the SMD. The assumptions in this area were felt to be reasonable, although the crop root zone depths play a large part in determining the final values, and are at best, rough estimates since they can vary widely.

EFFECTIVENESS OF POST-HARVEST RAIN IN REPLENISHING SMD

Precipitation events in the time period between harvest and planting play a large part in determining the amount of irrigation water needed for pre-plant irrigation. The amount of the total rainfall that actually infiltrates into the soil, and is available for use by the plant must be estimated and will vary widely depending on geographic, soil, and surface conditions. Rainfall for each of the districts was assumed to be equal to values recorded with a rain gage placed at Mendota Dam. All of the rainfall calculated as infiltrating was assumed to be beneficial, either meeting the leaching requirement, or satisfying the SMD. During years of heavy rainfall, such as 1983, this assumption may not be correct, since the water could simply deep percolate after the leaching requirement has been met. Fallow acreage was included in the calculation of the total rainfall contribution, since those acres may be planted in the following year. This is not a completely correct assumption, since some of the acreage previously in crops might also become fallow in the following year, yet the infiltrated rain on those acres will be counted as beneficially used in the PIE calculations. However, there is no practical way to take that into account in this study. Some rainfall events that occur during the months just prior to planting may also not fulfill pre-irrigation needs for the soil surface depth if the field has not been previously prepared, or the rainfall event occurs significantly before water is required for germination, so that the soil surface has time to dry out. The calculated value for rainfall contribution to SMD and the net leaching fraction (NLF) represents rainfall that has infiltrated, less the water that has been calculated as effective precipitation for the crops growing December through March. To be consistent, effective precipitation for the crops growing October through November should also be subtracted from the final rainfall contribution value, but was neglected due to the relative insignificance of the amount of rain involved for the additional work in determining it.

CROP ACREAGE

Crop acreage's are supplied by the districts and are assumed to be accurate. There are minor inconsistencies in the total number of cropped and fallow acres reported each year within the districts. There is some problem with the acreage figures being reported for water year versus crop year. This report uses the water year approach (Oct. 1- Sept. 31).

CROP ROTATION PATTERNS

A significant limitation on the final accuracy of the PIE numbers is the lack of data on the rotation pattern for specific acreage. The type of crop previously on the field has a large impact on the SMD at harvest, and subsequently on the amount of water needed for pre-plant irrigation. Also, since the leaching requirement is based on water quality, the irrigation requirements of the crop previously on the field will significantly impact the necessary leaching requirement. It is assumed in this study that these parameters can be generalized across the district and still produce valid results.

DISTRIBUTION UNIFORMITY OF THE IRRIGATION EVENTS

The study assumed that the affects of distribution uniformity during pre-irrigation events could be neglected since the water applied was significantly greater than that required (i.e. low PIE values) and therefore each portion of the field received at least the needed depth of irrigation water. Since the results indicate some years of high PIE values, the amount of beneficially used water during those years may need to be adjusted to reflect the effects of distribution uniformity.

CROP ETC REQUIREMENTS

Crop ETc requirements were determined based on the results of a previous 1992 DIE Report study, and were adjusted to reflect uneven cropping patterns. The adjusted values were used in this study.

POTENTIAL FUTURE WORK

- Calendar for infiltrated rainfall is September-March, should be October-March.
- Infiltrated rainfall based on estimating need to be verified.
- Effective precipitation for crops growing October-November is not removed from the total rainfall contribution as it should be.

DISCUSSION OF DISTRICT PRE-PLANT IE

Figures 17 through 21 represent the values determined by the pre-plant irrigation efficiency analysis. A detailed description of the Spreadsheets used to calculate the PIE is included in Approach A. In order to visually recognize the need for leaching in the districts, the figures show a graph of the potential beneficial water use and the actual water delivered during the PIE time frame.

PACHECO

Water delivery values for Pacheco are suspect. The values were supplied by the Bureau of Reclamation and the extreme variability of the numbers, particularly the low numbers in 1985 and 1986, indicate the reported values are not correct. In addition, the Bureau numbers are inconsistent with the yearly values reported by the district.

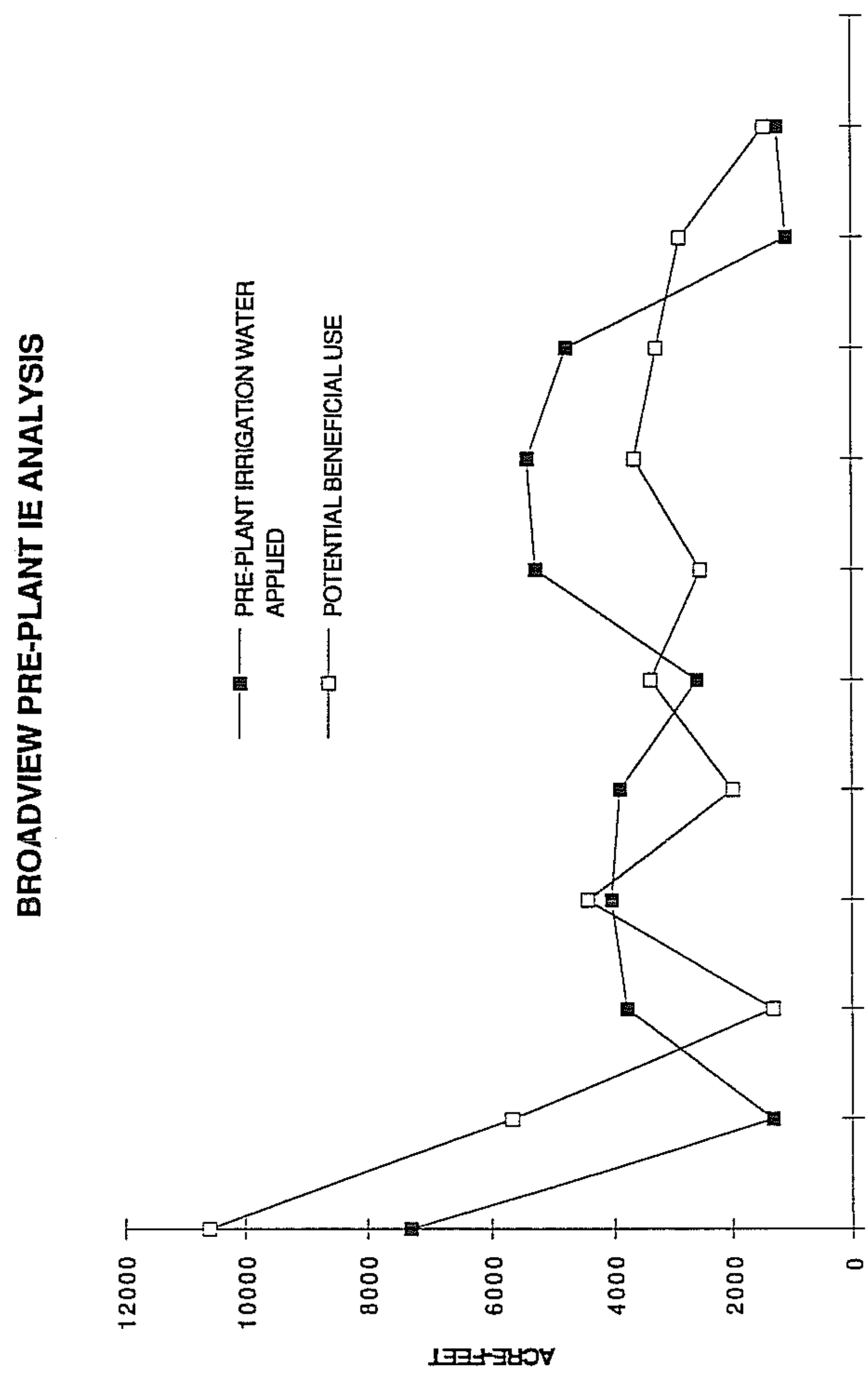

BROADVIEW PRE-PLANT IE ANALYSIS
PRE-PLANT IRRIGATION WATER APPLIED
POTENTIAL BENEFICIAL USE
ACRE-FEET
12000
10000
8000
6000
4000
2000
0
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

Figure 17

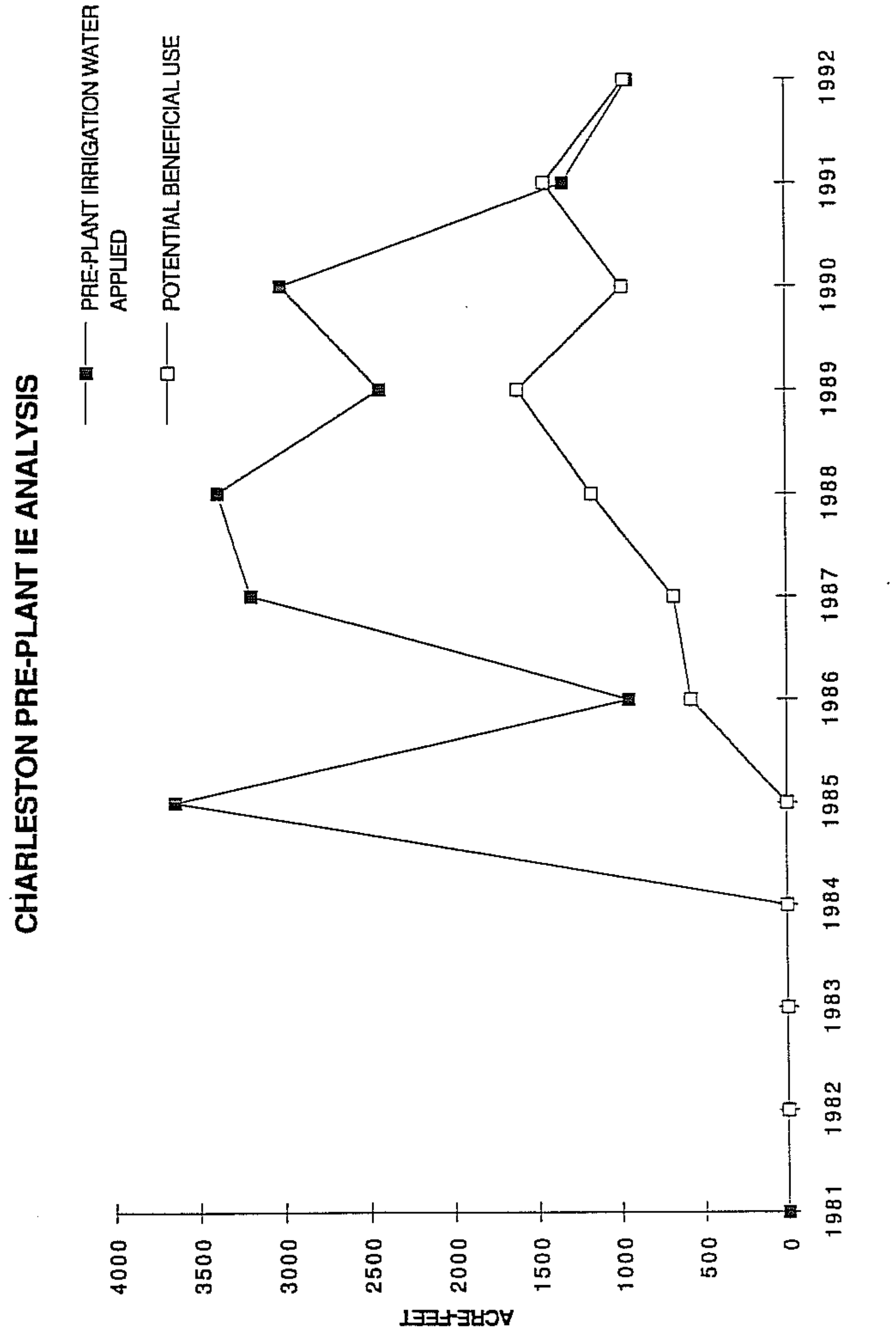

CHARLESTON PRE-PLANT IE ANALYSIS
PRE-PLANT IRRIGATION WATER APPLIED
POTENTIAL BENEFICIAL USE
ACRE-FEET
4000
3500
3000
2500
2000
1500
1000
500
0
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

Figure 18

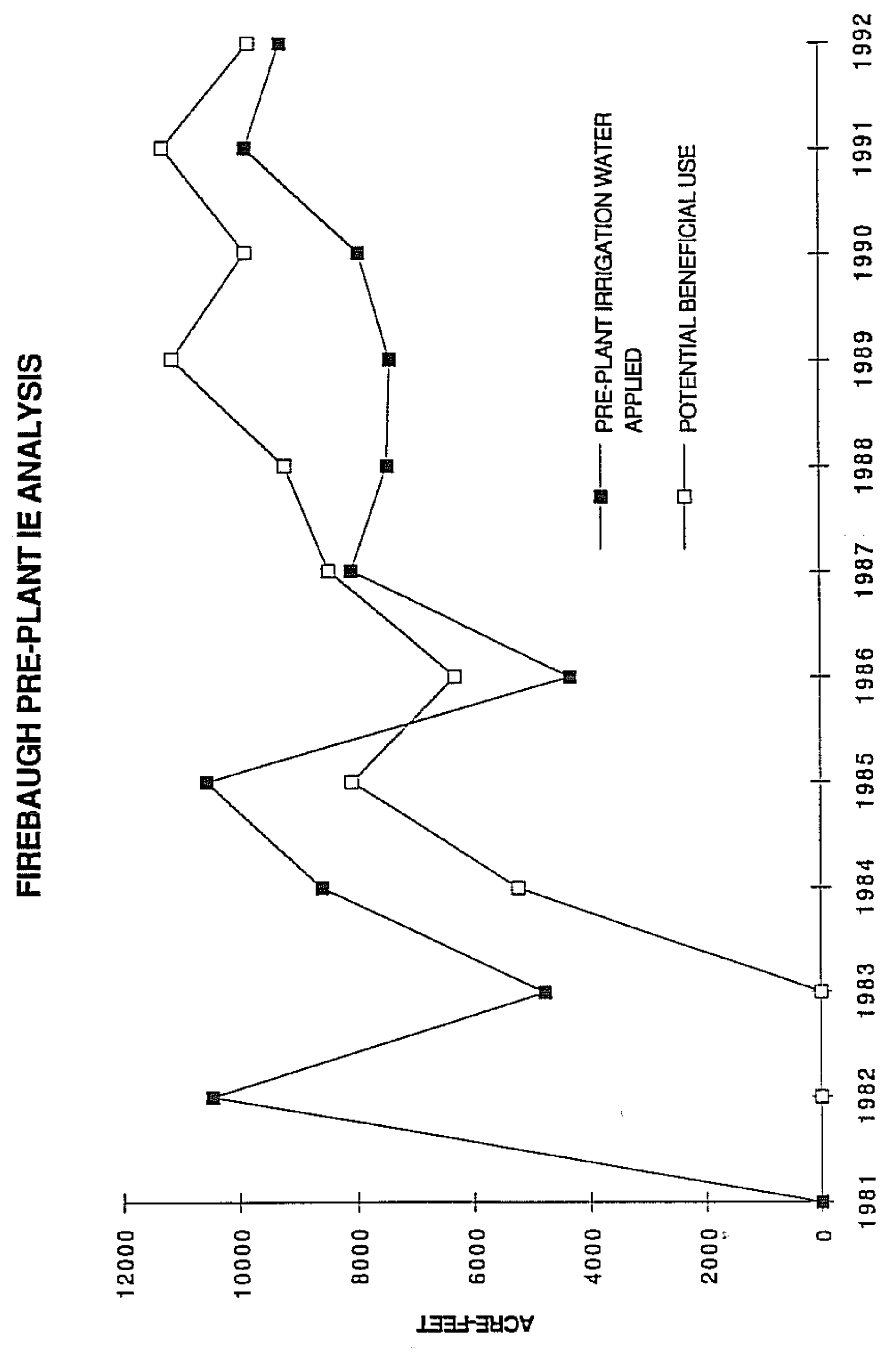
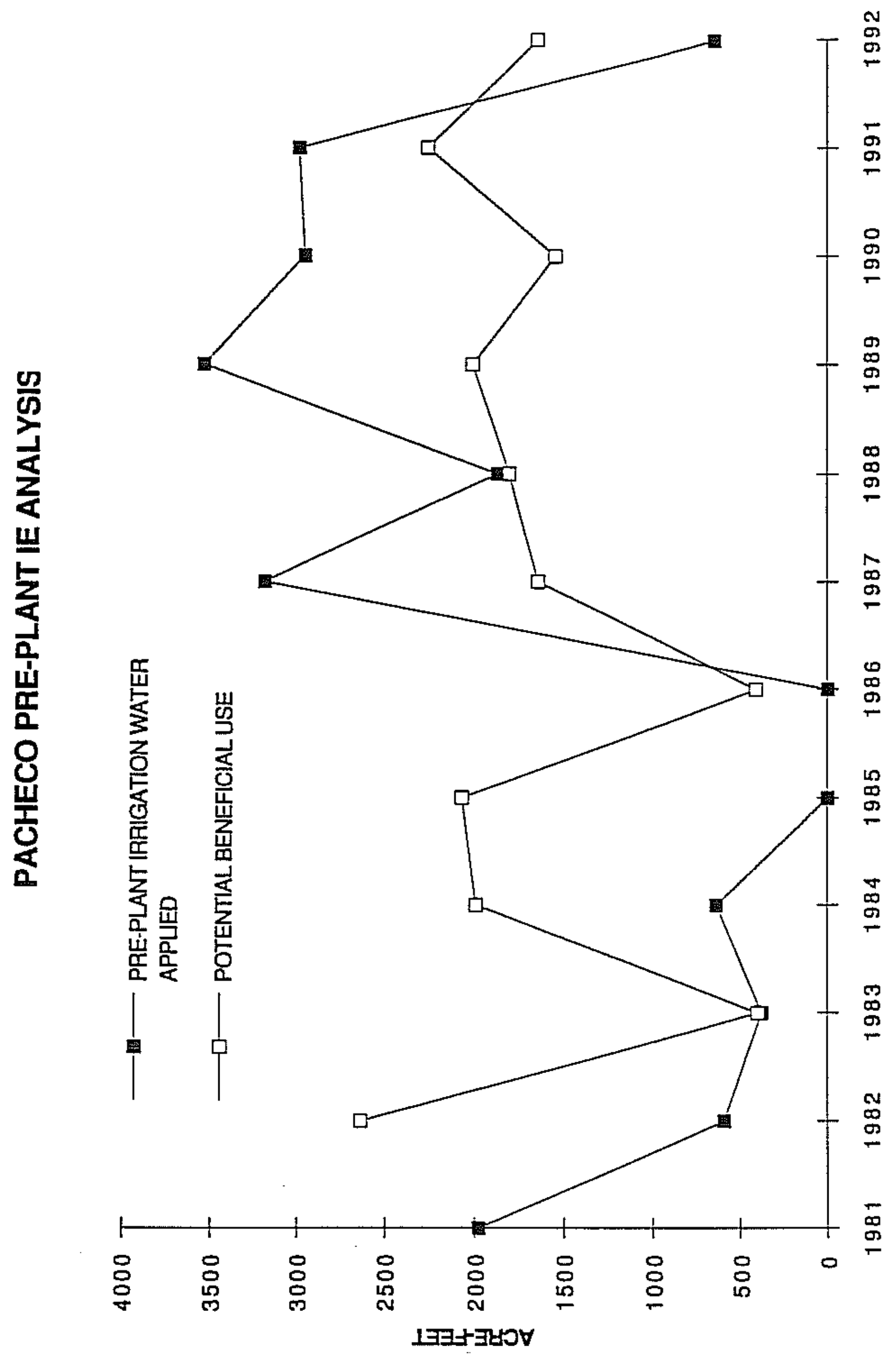

FIREBAUGH PRE-PLANT IE ANALYSIS
PRE-PLANT IRRIGATION WATER APPLIED
POTENTIAL BENEFICIAL USE
ACRE-FEET
12000
10000
8000
6000
4000
2000
0
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

Figure 19


PACHECO PRE-PLANT IE ANALYSIS
PRE-PLANT IRRIGATION WATER APPLIED
POTENTIAL BENEFICIAL USE
ACRE-FEET
4000
3500
3000
2500
2000
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1000
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1981
1982
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1989
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1991
1992

Figure 20

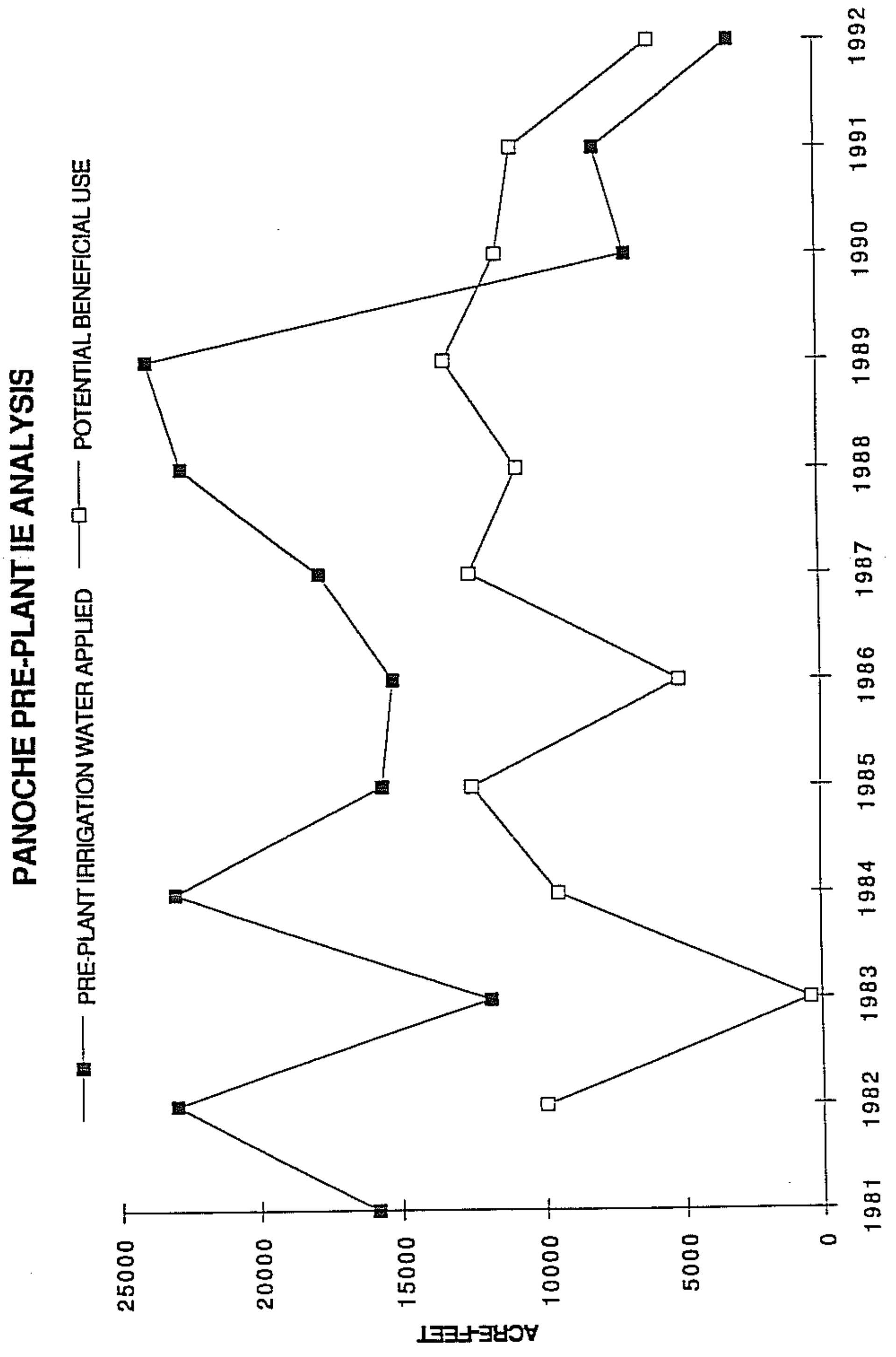

PANOCHE PRE-PLANT IE ANALYSIS
PRE-PLANT IRRIGATION WATER APPLIED
POTENTIAL BENEFICIAL USE
ACRE-FEET
25000
20000
15000
10000
5000
0
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

Figure 21

FIREBAUGH

Water delivery in 1983 and 1986 is significantly less than in other years. Low rainwater contribution in 1987 is due to the amount of rain that occurred in February and March of that year which was counted as effective rainfall for crops growing during that time period (mostly wheat), and was subtracted from the amount of rainfall contributing to SMD and NLF. No crop acreage values for 1982 and 1983 were available.

BROADVIEW

Very high ECw values drive the PIE for 1982 and 1983. A low value of 35% in 1984 is most likely due to making up for leaching requirement from previous years.

CHARLESTON

No crop acreages for 1981-1985 were available. Low water supply in 1986 is coincident with increased rainfall during that year. Monthly water supply values reported by the Bureau are inconsistent with the yearly values reported by the districts; with district values generally considered more accurate.

PANOCHE

Low PIE in 1983 coincide with high rainfall, a trend which is also apparent in most of the other districts since potential beneficial use drops markedly.

ANALYSIS

Useful trends can be read from the figures generated for Panoche, Firebaugh, and Broadview, while Pacheco and Charleston appear less reliable.

High pre-plant irrigation efficiencies in 1990-1992 may be unrealistic since the water applied is less than that theoretically needed for crop requirements and leaching. Deferral of leaching will lead to a need for large irrigation events in future years to compensate; driving down the PIE.

Water use does indicate a compensation for years of high and low rainfall during pre-irrigation. During years of high rainfall, less pre-plant irrigation water is applied, and when the rainfall is less, pre-plant irrigation water increases. The last few years indicate that rainfall has had less effect on the amount of irrigation water applied, perhaps since leaching requirements are not being taken care of, so pre-plant irrigation water needed to account for low annual rainfall is not being applied. This is shown graphically for Panoche, Firebaugh, and Broadview in **Figures 22 through 24.**

Trends indicate that leaching requirements are met during high rainfall years, when water is abundant.

CONCLUSIONS

The study of the pre-plant irrigation efficiencies in the Grassland Basin Irrigation and Drainage Study depends on the application of broad-based and theoretical assumptions about agricultural practices to highly variable and site specific cropping and irrigation patterns. Furthermore, the information available from the water districts involved is general in nature and at times questionable in its accuracy. Given these limitations, quantifying the data and arriving at specific numbers for district-wide irrigation efficiencies for a certain portion of the cropping season is a task which requires a certain amount of professional skill to evaluate the results. The intention in this portion of the study was to obtain numbers which would reflect trends in pre-plant irrigation efficiencies and indicate the degree of need for modifying irrigation practices during the time of year when pre-plant irrigation occurs. The conclusions which result from this examination show trends which are expected, supporting the validity of the conclusions which may be drawn.

- The data indicate that growers are adjusting water deliveries in response to the quantity of effective rainfall.
- Low PIE values can generally be explained where growers are applying excess water in one year to satisfy leaching requirements from previous years.
- High PIE values from 1990-1992 in some of the districts reflect inadequate water supplied for leaching.
- 1993 can be expected to be a low PIE year if water was available.

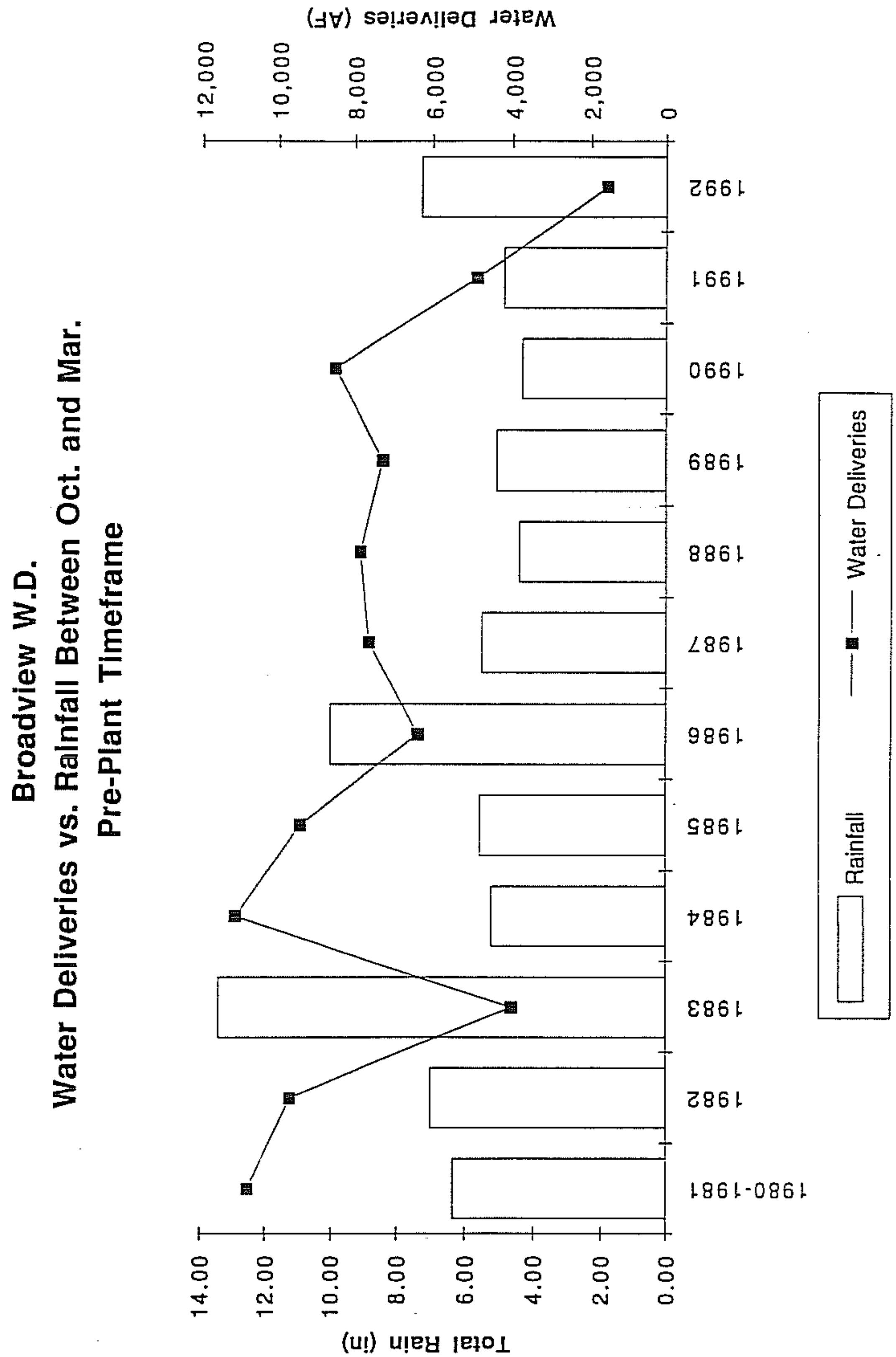

Broadview W.D.
Water Deliveries vs. Rainfall Between Oct. and Mar.
Pre-Plant Timeframe
Water Deliveries (AF)
12,000
10,000
8,000
6,000
4,000
2,000
0
Total Rain (in)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1980-1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
Rainfall
Water Deliveries

Figure 22

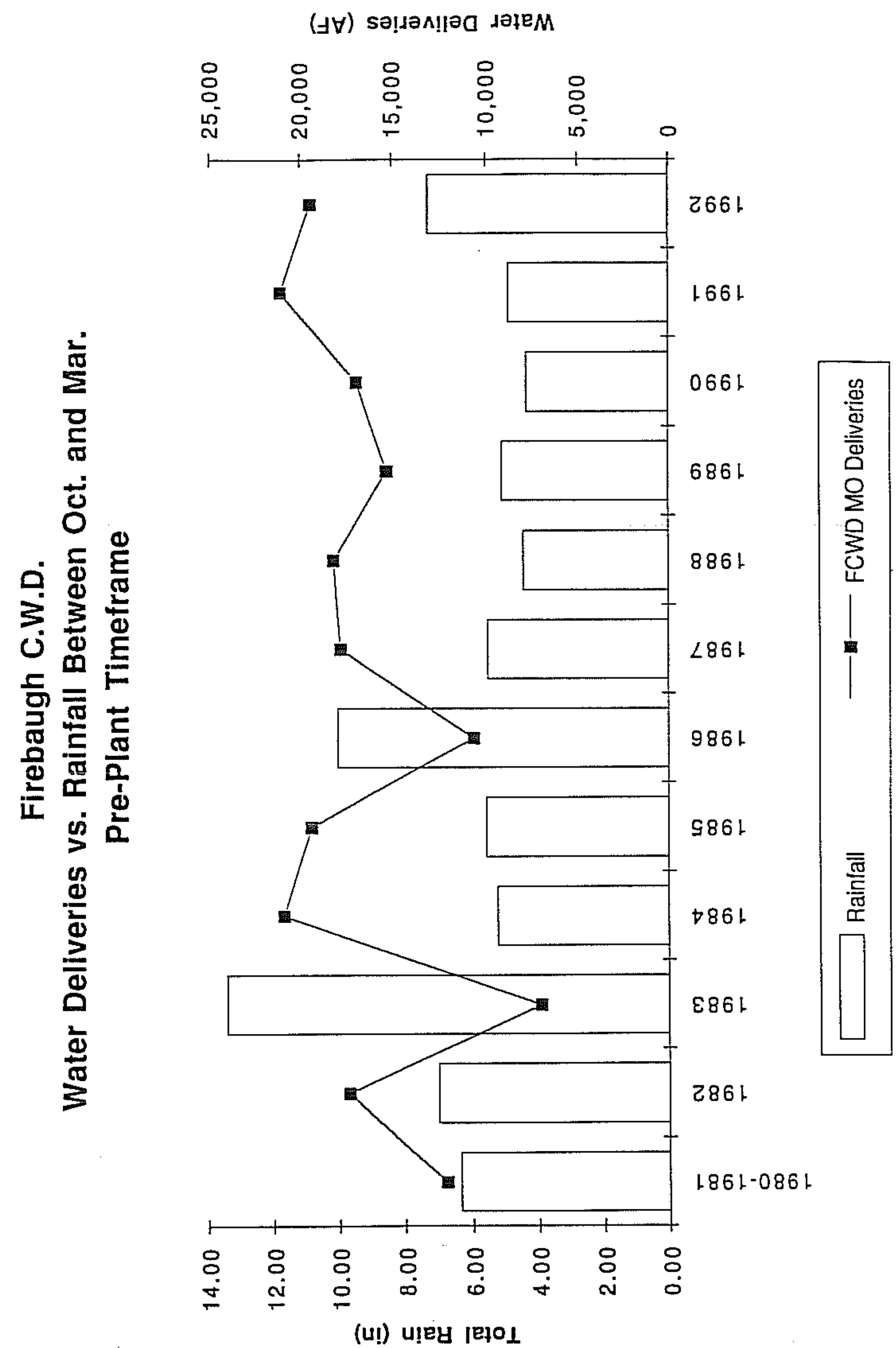

Firebaugh C.W.D.
Water Deliveries vs. Rainfall Between Oct. and Mar.
Pre-Plant Timeframe
Water Deliveries (AF)
25,000
20,000
15,000
10,000
5,000
0
Total Rain (in)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1980-1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
Rainfall
FCWD MO Deliveries

Figure 23

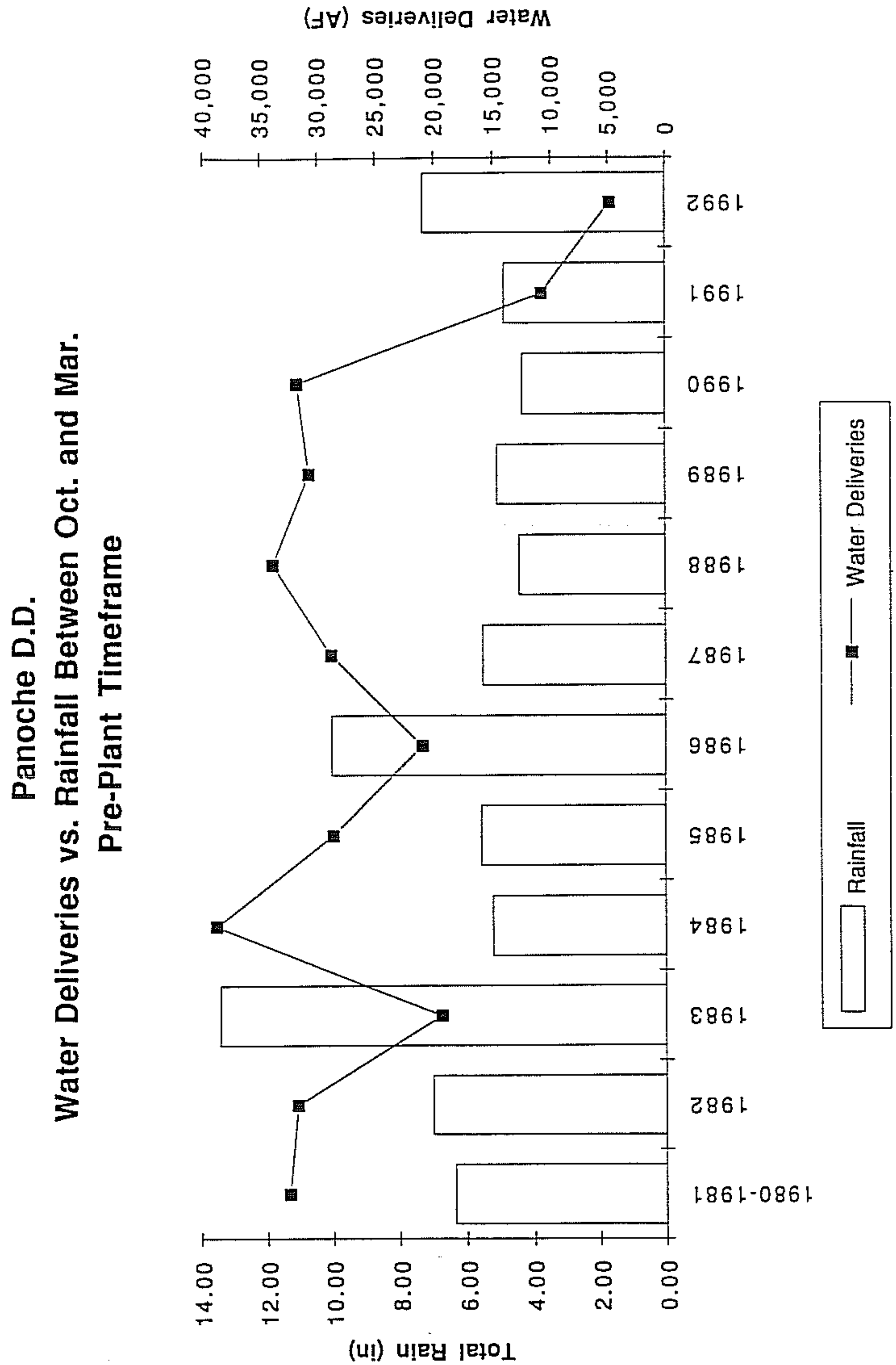

Panoche D.D.
Water Deliveries vs. Rainfall Between Oct. and Mar.
Pre-Plant Timeframe
Water Deliveries (AF)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Total Rain (in)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1980-1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
Rainfall
Water Deliveries

Figure 24

SECTION 5

DISTRICT IRRIGATION EFFICIENCY: WATER BALANCE APPROACH

OVERVIEW

The following section of the study was designed to be a check against the DIE using the ETc approach. The Water Balance approach used the reported district drainage (and its quality) to determine the DIE and to compare it with the ETc approach. If a district acts hydrologically as a "bathtub", this is a reasonable approach.

Since 1985, additional data has been collected and reported for the drainage volumes discharged by the districts. Using this data and some assumptions regarding subsurface water flows, an estimate of the irrigation efficiency using a "bathtub" or water balance approach was completed in order to verify the validity of the values generated by the theoretical ETc approach. The water balance approach is described in this section of the report.

The DIE values were determined for water years 1986 to 1992 depending on what information was available. In this report, 1986 refers to the water year October 1, 1985 through September 30, 1986. The goal was to verify the relative values of the DIE estimates using the ETc approach.

This section represents **Level VI**, from the section on the ETc approach where a check of irrigation efficiency is made using the bathtub approach. Irrigation Efficiency is defined as:

$$IE = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied}} \times 100$$

This section calculates the irrigation water beneficially used based on a water balance. Where the amount of water delivered to the fields is known and the drainage volumes are known, estimates of the subsurface components were made to find the beneficial use component. **Figure 25** shows the model used to describe the water balance.

DISTRICT WATER BALANCE

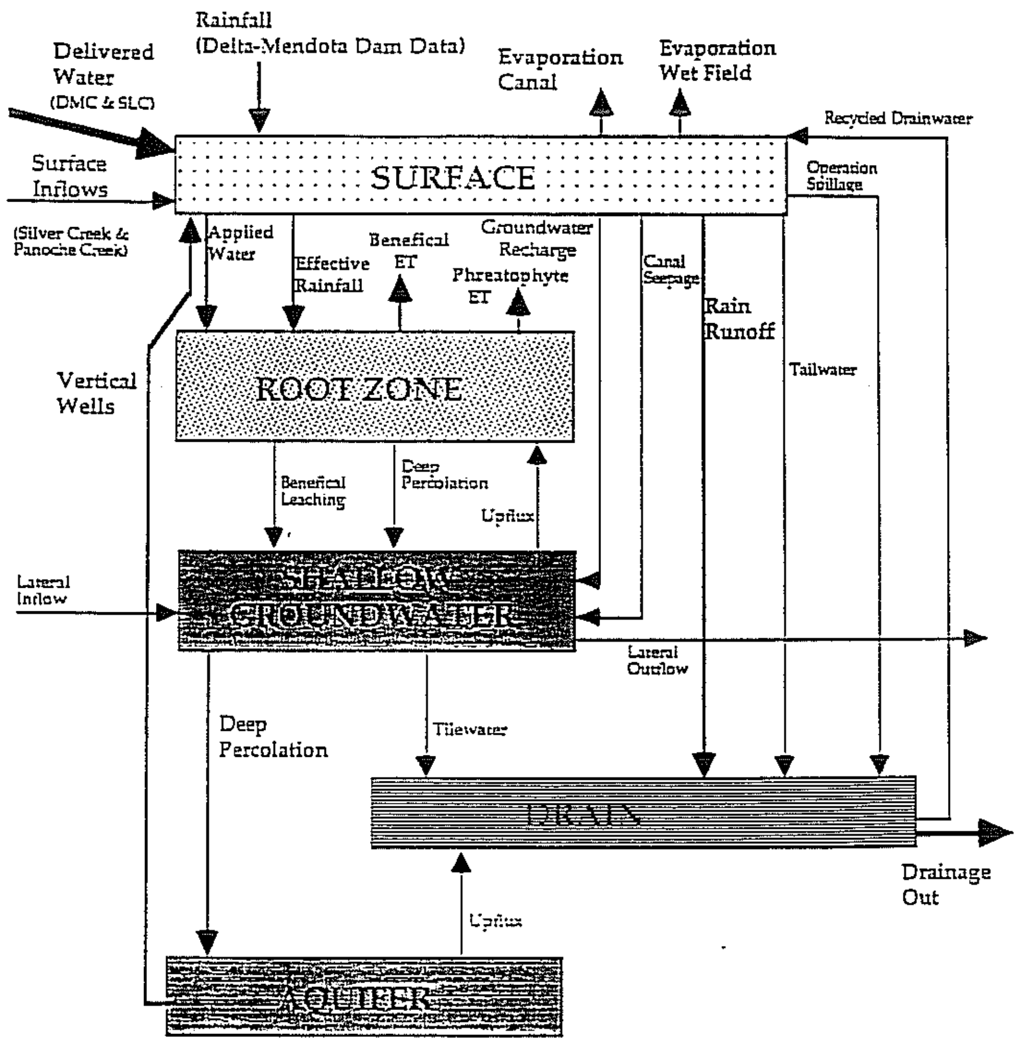


Figure 25

PROCEDURE

A single spreadsheet was developed for the entire study area using the Water Balance approach. The spreadsheet is available in PC-Compatible format or Macintosh format. The entire spreadsheet in its original format is included in **Appendix F.**

The following tables represent the calculation of the amount of water that is beneficially used. Only 1986 through 1992 is included because drainage data collection and recording started in 1985 for most of the districts.

Table 45 shows the total amount of water delivered to the districts including the water from the Delta Mendota Canal, the San Luis Canal, pumps and any surface water that may have entered the canal systems.

Table 45
Water Delivery (IN)
Values in AF

		Variable	1986	1987	1988	1989	1990	1991	1992
Panoche		W1: PeDD	92,487	98,119	97,196	91,300	81,258	69,706	63,416
Pacheco		W2: PaWD	7,770	9,756	10,217	13,063	11,569	11,572	8,107
Charleston		W3: SLWD	10,264	13,891	14,428	12,263	11,127	10,218	9,630
Eastside Districts		W4=W5+W6+W7	102,667	119,108	117,735	106,574	97,567	86,394	83,201
	FCWD	W5: FCWD	62,966	79,545	75,106	70,326	63,903	57,141	59,569
	BWD	W6: BWD	24,628	23,308	25,891	25,200	20,582	12,902	9,086
	CCID	W7: CCID	15,072	16,255	16,738	11,049	13,081	16,351	14,546
Total Vol. (AF)		W8=W1+W2+W3 +W4	213,188	240,874	239,576	223,200	201,521	177,890	164,354

Note the water delivered for the districts decreased from a high of 241,000 AF in 1987 to 164,000 AF in 1992 due to the drought conditions.

Table 46 shows the weather data for the study area. The rain was from the Mendota Dam site. The effective rain was based on 50% of the rain. The runoff from rain events was estimated to be 15%. The ETo data is from CIMIS #7 at Firebaugh, **Table 47** is the acreage data reported by the districts.

Table 46
Rain and ETo Data

			1986	1987	1988	1989	1990	1991	1992
Total Rain	(in)	P1	11.0	5.7	5.9	6.7	6.1	5.1	7.5
Effective Rain	(in)	P2: Est. of 50%	5.5	2.8	2.9	3.4	3.0	2.5	3.7
Rain Runoff	(in)	P3: Est. of 15%	1.7	0.8	0.9	1.0	0.9	0.8	1.1
ETo	(in)	R1: CIMIS	55	57	56	57	57	56	56

Table 47
Acreage (Ac)

			1986	1987	1988	1989	1990	1991	1992
Panoche		A1: PeDD	33,153	32,208	33,795	35,686	31,799	28,126	27,742
Pacheco		A2: PaWD	3,500	4,028	4,179	3,648	4,254	4,369	3,705
Charleston		A3: SLWD	2,897	3,724	3,582	3,602	3,494	3,890	3,890
Eastside Districts		A4=A5+A6+A7	32,534	33,923	37,237	37,498	38,054	34,772	34,277
	FCWD	A5: FCWD	19,825	20,981	23,282	24,746	25,458	24,678	24,894
	BWD	A6: BWD	8,169	7,870	8,736	8,686	8,160	5,539	4,483
	CCID	A7: CCID	4,540	5,072	5,219	4,066	4,436	4,555	4,900
Total Acreage		**A8=A1+A2+ A3+A4**	72,084	73,883	78,793	80,434	77,601	71,157	69,614
Fallow Ac		**A9**	4,632	3,439	2,021	2,429	5,846	11,792	13,584

Table 48 shows the estimated evaporation by the canals in the districts. A base value was estimated based on the miles of canals and the size of the canals. The annual amount was varied by the ETo. **Table 49** shows the estimated evaporation from canals and fields. Both these tables represent non-beneficial water losses for the DIE calculation.

Table 48
Canal Evaporation
Values in AF

			1986	1987	1988	1989	1990	1991	1992
Panoche		E1: Est. 200 AF Vary by ETo	192	202	196	199	199	197	197
Pacheco		E2: Est. 100 AF Vary by ETo	96	101	98	99	99	98	98
Charleston		E3: Est. 100 AF Vary by ETo	96	101	98	99	99	98	98
Eastside		E4=E5+E6+E7	384	404	393	397	397	393	393
Districts									
	FCWD	E5: Est. 150 AF Vary by ETo	144	151	147	149	149	147	147
	BWD	E6: Est. 100 AF Vary by ETo	96	101	98	99	99	98	98
	CCID	E7: Est. 100 AF Vary by ETo	96	101	98	99	99	98	98
Total (AF)		**E8=E1+E2+E3+E4**	768	808	785	795	795	787	787

Table 49
Evaporation - Phreatophytes, Fields, Head Ditches
Values in AF

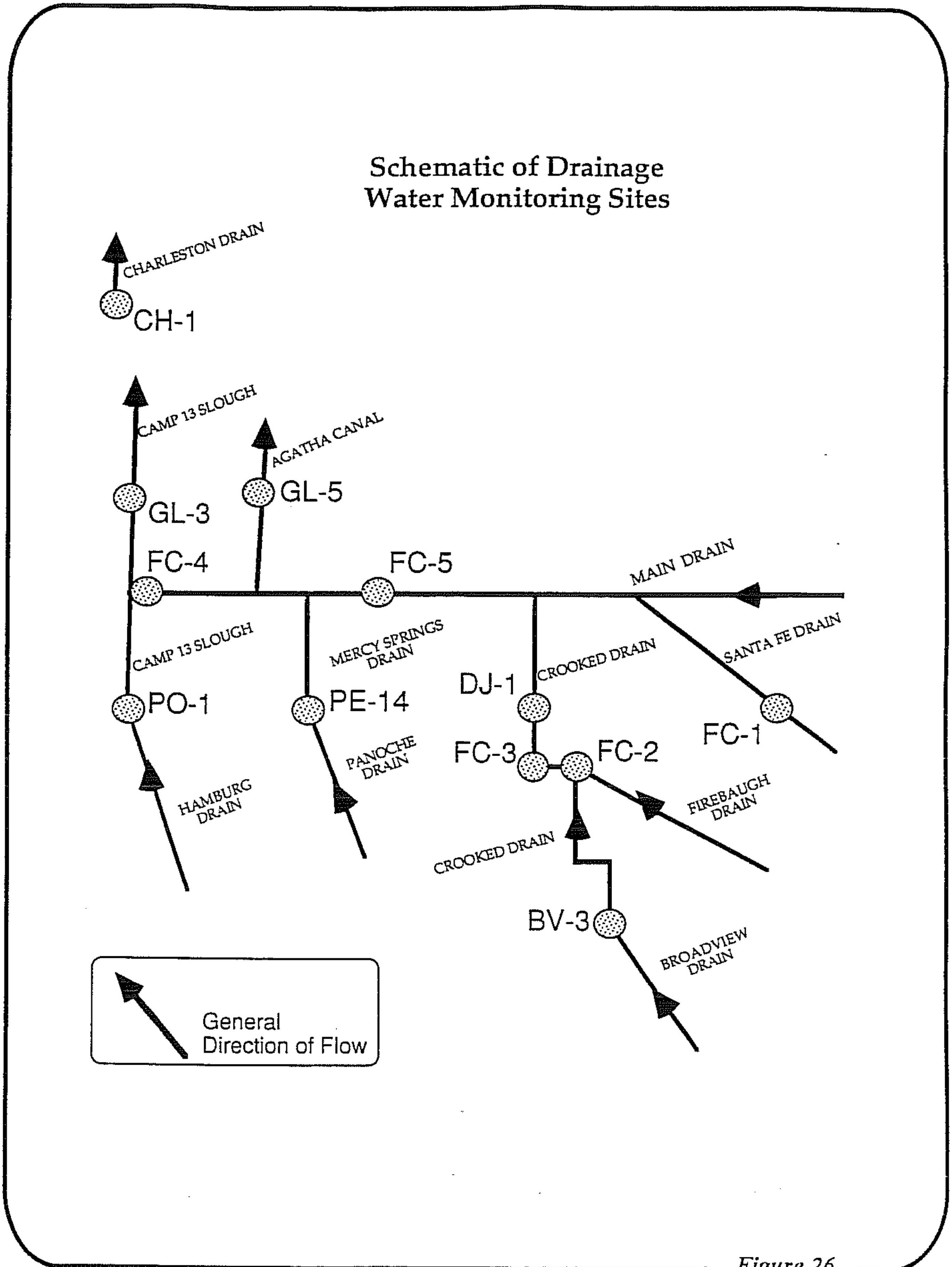
			1986	1987	1988	1989	1990	1991	1992
Panoche		E11: Est. 3% of Delivered	2,775	2,944	2,916	2,739	2,438	2,091	1,902
Pacheco		E12: Est. 3% of Delivered	233	293	307	392	347	347	243
Charleston		E13: Est. 3% of Delivered	308	417	433	368	334	307	289
Eastside		E14=E15+E16+E17	3,080	3,573	3,532	3,197	2,927	2,592	2,496
Districts									
	FCWD	E14: Est. 3% of Delivered	1,889	2,386	2,253	2,110	1,917	1,714	1,787
	BWD	E15: Est. 3% of Delivered	739	699	777	756	617	387	273
	CCID	E16: Est. 3% of Delivered	452	488	502	331	392	491	436
Total Vol. (AF)		**E18=E11+E12+E13+E14**	6,396	7,226	7,187	6,696	6,046	5,337	4,931

Table 50 shows the estimated amount of applied water that will be accounted for by infiltration or losses to the drains. This includes losses such as operational discharges to the drains. The calculation is simply the total water delivered less the evaporation estimates.

Table 50
Total Infiltrated or in Drains
Values in AF

			1986	1987	1988	1989	1990	1991	1992
Panoche		IN1=W1-E1-E11	89,520	94,973	94,084	88,362	78,622	67,418	61,317
Pacheco		IN2=W2-E2-E12	7,441	9,362	9,812	12,572	11,123	11,127	7,765
Charleston		IN3=W3-E3-E13	9,860	13,373	13,897	11,796	10,694	9,813	9,243
Eastside		IN4=W4-E4-E14	99,203	115,131	113,810	102,980	94,243	83,409	80,312
Districts									
	FCWD	IN5=W5-E5-E15	60,933	77,007	72,705	68,067	61,837	55,279	57,634
	BWD	IN6=W6-E6-E16	23,793	22,508	25,016	24,345	19,865	12,417	8,715
	CCID	IN7=W7-E7-E17	14,524	15,666	16,138	10,618	12,590	15,762	14,012
Total Vol. (AF)		IN8=W8-E8-E18	206,024	232,840	231,603	215,710	194,681	171,766	158,637

Refer to **Figure 26** for the location of the discharge points. **Table 51** shows the amount of drainage flows from the drainage measurement points in the districts. It must be noted that based on visual observation, not all of the measurement sites have the same degree of accuracy. The measurement site at PE-14 is a good measurement site, while the measurement site at PO-1 is a poor measurement site. Future efforts need to focus on improving these measurement sites for accuracy and standardizing the water quality collection process. **Appendix G** contains a selected portion of the graphical analysis of the water quality data. It was determined that due to inconsistencies in the format of the reported data and uncertainties of the water volumes at the times of the water quality measurements, the water quality data was not incorporated into this study of the irrigation efficiency. However, increases in the irrigation efficiency will undoubtedly increase concentrations in the discharges from the districts.



Schematic of Drainage
Water Monitoring Sites
CHARLESTON DRAIN
CH-1
CAMP 13 SLOUGH
AGATHA CANAL
GL-3
GL-5
FC-4
FC-5
MAIN DRAIN
CAMP 13 SLOUGH
MERCY SPRINGS DRAIN
CROOKED DRAIN
SANTA FE DRAIN
DJ-1
PO-1
PE-14
FC-3
FC-2
FC-1
PANOCHE DRAIN
HAMBURG DRAIN
FIREBAUGH DRAIN
CROOKED DRAIN
BV-3
BROADVIEW DRAIN
General
Direction of Flow

Figure 26

Table 51
Water Drainage (OUT)
Values in AF

		1986	1987	1988	1989	1990	1991	1992
Panoche	D1: PE-14	33,257	34,724	30,144	24,875	19,835	13,475	13,532
Pacheco	D2: PO-1	3,884	5,176	2,664	5,122	3,160	2,716	2,716
	(2337,3772,3231,655)							
Charleston	D3: CH-1	3,186	4,769	6,136	2,799	2,126	781	781
Eastside Districts	D4: FC-5	31,191	32,265	26,041	22,626	16,964	13,491	13,491
Total Vol. (AF)	D5=D1+D2+D3+D4	71,518	76,934	64,985	55,422	42,085	30,463	30,520

Table 52 shows the percentage of the drainage water to the delivered water. This table is deceiving since there can be waters entering the system that are beyond the control of the district. For example, subsurface flows from regions outside of the district boundaries. Or surface runoff from rainfall that enters the drains. Also some of the water may be beneficial by removing harmful salts from the rootzone.

Table 52
Percent of Delivered Water vs. Water in Drains

		1986	1987	1988	1989	1990	1991	1992
Panoche	Water IN/Water OUT	36%	35%	31%	27%	24%	19%	21%
Pacheco	D2/W2	50%	53%	26%	39%	27%	23%	34%
Charleston	D3/W3	31%	34%	43%	23%	19%	8%	8%
Eastside Districts	D4/W4	30%	27%	22%	21%	17%	16%	16%
Total Vol. (AF)	Calc	34%	32%	27%	25%	21%	17%	19%

Table 53 shows the amount of drain water that is beneficial to the district by removing harmful salts. These values were calculated by using a desired rootzone threshold ECe of 2.5 dS/m.

Table 53
Water For Leaching
Values in AF

			1986	1987	1988	1989	1990	1991	1992
Panoche		L1: From DIE - ETc	4,176	4,430	4,388	4,122	3,669	4,135	3,762
Pacheco		L2: From DIE ETc	787	988	1,035	1,835	1,626	1,626	1,139
Charleston		L3: From DIE ETc	331	688	753	543	561	506	503
Eastside Districts		L4= L5+L6+97	4,918	5,419	6,084	5,283	5,383	4,752	4,136
	FCWD	L5: From DIE ETc	2,843	3,592	3,391	3,175	2,885	2,580	2,690
	BWD	L6: From DIE ETc	1,395	1,093	1,937	1,609	1,907	1,434	790
	CCID	L7: From DIE ETc	681	734	756	499	591	738	657
Total Vol. (AF)		**L8=L1+L2+L3+L4**	10,212	11,525	12,260	11,783	11,238	11,019	9,540

Table 54 shows the amount of drain water that is estimated from sources outside of the district that are subsurface flows. An estimate was provided from John Fio (personal communication) and the details are included in **Appendix H.**

Table 54
Subsurface Baseflow
Values in AF

			1986	1987	1988	1989	1990	1991	1992
Panoche		B1-B3:From John Fio	4,800	4,300	2,900	3,700	2,000	1,500	906
Pacheco		Personal Communication	544	544	549	605	0	451	575
Charleston			30	30	30	1	0	0	30
Eastside Districts		B4=B5+B6+B7	1,709	1,204	1,198	1,638	1,400	920	961
	FCWD	B5-B7:From John Fio	609	438	524	501	509	368	409
	BWD	Personal Communication	600	266	174	637	391	52	52
	CCID		500	500	500	500	500	500	500
Total Vol. (AF)		B8=B1+B2+B3+B4	7,083	6,078	4,677	5,944	3,400	2,871	2,472

Table 55 shows the amount of drain water that was from rain runoff. These volumes have not been historically recorded for the districts. Some of the districts could have much larger numbers than were estimated because they might spill water for another district to avoid flooding during rain events. This tended to increase the volumes of drainage flows that did not originate with the districts.

Table 55
Rain Runoff
Values in AF

			1986	1987	1988	1989	1990	1991	1992
Panoche		R1:From DIE ETc	4,571	2,279	2,488	2,989	2,405	1,775	2,583
Pacheco		R2:From DIE ETc	483	285	308	306	322	276	345
Charleston		R3:From DIE ETc	399	263	264	302	264	246	362
Eastside Districts		R4=R5+R6+R7	4,486	2,400	2,742	3,140	2,878	2,195	3,192
	FCWD	R5:From DIE ETc	2,733	1,484	1,714	2,072	1,925	1,558	2,318
	BWD	R6:From DIE ETc	1,126	557	643	727	617	350	417
	CCID	R7:From DIE ETc	626	359	384	341	335	288	456
Total Vol. (AF)		R8=R1+R2+R3+R4	9,939	5,227	5,801	6,736	5,869	4,492	6,483

Table 56 shows the amount of drain water that was evaporated before reaching the outlet of the district. This value was roughly estimated by the determining the area in drains and factoring in the evaporation rate of an open water body. The evaporation amounts were then varied by month.

Table 56
Drain Evaporation - Phreatophytes & Water Surfaces
Values in AF

			1986	1987	1988	1989	1990	1991	1992
Panoche		E19: Est. 500 AF Vary by ETo	480	505	491	497	497	492	492
Pacheco		E20: Est. 250 AF Vary by ETo	240	252	245	248	248	246	246
Charleston		E21: Est. 250 AF Vary by ETo	240	252	245	248	248	246	246
Eastside Districts		E22=E15+E16+E17	960	1,010	982	993	993	983	983
	FCWD	E23: Est. 350 AF Vary by ETo	336	353	344	348	348	344	344
	BWD	E24: Est. 250 AF Vary by ETo	240	252	245	248	248	246	246
	CCID	E25: Est. 250 AF Vary by ETo	240	252	245	248	248	246	246
Total Vol. (AF)		**E26=E11+E12+E13+E14**	1,920	2,020	1,964	1,987	1,987	1,966	1,966

Table 57 shows the amount estimated amount of water that leaks to the deep aquifer below the Corcoran Clay. These estimates were provide by John Fio (personal communication) and details are include in **Appendix H.** These values represent drainage from the districts that does not appear in the drains but travels subsurface to the lower aquifer. These values are constant since it is assumed that there is some drainage occuring from the entire area of the districts.

Table 57
Deep Percolation Losses below Corcoran Clay
Values in AF

			1986	1987	1988	1989	1990	1991	1992
Panoche		DP1=.31 AF/A x Acres	10,587	10,587	10,587	10,587	10,587	10,587	10,587
Pacheco		DP2=.31 AF/A x Acres	1,367	1,367	1,367	1,367	1,367	1,367	1,367
Charleston		DP3=.31 AF/A x Acres	1,122	1,122	1,122	1,122	1,122	1,122	1,122
Eastside Districts		DP4=DP5+DP6+DP7	10,019	10,019	10,019	10,019	10,019	10,019	10,019
	FCWD	DP5=.21 AF/A x Acres	6,234	6,234	6,234	6,234	6,234	6,234	6,234
	BWD	DP6=.26 AF/A x Acres	2,798	2,798	2,798	2,798	2,798	2,798	2,798
	CCID	DP7=.21 AF/A x Acres	987	987	987	987	987	987	987
Total Vol. (AF)		**DP8=DP1+DP2+DP3+DP4**	23,094	23,094	23,094	23,094	23,094	23,094	23,094

Table 58 shows the calculation of the non-beneficial water from the districts. The equation for the non-beneficial water is as follows:

Non-Beneficial Water

= Drainage - Leaching -Baseflow -Rain Runoff +Drain Evap. +Deep Percolation (Deep Aquifer)

= Table 51 - Table 53 - Table 54 - Table 55 + Table 56 + Table 57

Note that non-beneficial water includes some proportion of tailwater, tile water, and operational spill water. It was felt there was not an easy method to obtain the relative amounts of the individual components. The tile water can be from poor irrigation timing or from the distribution uniformity of the irrigation systems. Note that from 1987 to 1992 the volume of non-beneficial water decreased 50%.

Table 58
Non-Beneficially Used Water
Values in AF

		1986	1987	1988	1989	1990	1991	1992
Panoche	NB1=D1-L1-B1-R1+E19+DP1	30,777	34,807	31,445	25,147	22,845	17,143	17,359
Pacheco	NB2=D2-L2-B2-R2+E20+DP2	3,677	4,978	2,385	3,991	2,828	1,976	2,270
Charleston	NB3=D3-L3-B3-R3+E21+DP3	3,788	5,161	6,456	3,323	2,671	1,397	1,254
Eastside Districts	NB4=D4-L4-B4-R4+E22+DP4	31,057	34,271	27,018	23,577	18,315	16,626	16,203
Total Vol. (AF)	**NB8=NB1+NB2+NB3 +NB4**	69,299	79,217	67,304	56,039	46,659	37,142	37,086

Table 59 shows the calculation of the beneficial water from the districts. The beneficially used water is the difference between the water that was accounted for in the drains (IN1 through IN5) and the non-beneficial component (NB1 through NB5).

Table 59
Beneficially Used Water
Values in AF

		1986	1987	1988	1989	1990	1991	1992
Panoche	B1=IN1-NB1	58,743	60,166	62,639	63,215	55,777	50,275	43,958
Pacheco	B2=IN2-NB2	3,764	4,384	7,428	8,580	8,294	9,150	5,496
Charleston	B3=IN3-NB3	6,072	8,212	7,441	8,473	8,023	8,416	7,989
Eastside Districts	B4=IN4-NB4	68,146	80,860	86,792	79,403	75,928	66,783	64,109
Total Vol. (AF)	B5=B1+B2+B3+B4	136,725	153,622	164,299	159,671	148,022	134,625	121,552

Table 60 shows the calculation of the district irrigation efficiency based on the following equation:

$$IE = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied}} \times 100$$

Also shown on this table is the comparison to the Regional IE estimate from the ETc approach. The values trend similar to each other indicating increasing irrigation efficiencies as the drought continued into the 6th year (1992). **Figure 27** shows the graphical relationship between the two approaches of determining the irrigation efficiency. This graph shows that the water balance approach verifies the assumptions of the DIE analysis using the ETc approach. The differences in the early years probably reflect poor water volume measurements at the beginning of the water masurement efforts. The values are 5% or less difference starting in 1987. The values are within 3% in the years 1989 through 1992.

Table 60
Regional Irrigation Efficiency - Water Balance Approach

		1986	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Panoche (DIE)	IE1=B1/W1	64%	61%	64%	69%	69%	72%	69%
Pacheco (DIE)	IE2=B2/W2	48%	45%	73%	66%	72%	79%	68%
Charleston (DIE)	IE3=B3/W3	59%	59%	52%	69%	72%	82%	83%
Eastside Districts	IE4=B4/W4	66%	68%	74%	75%	78%	77%	77%
Regional IE	IE8=B8/W8	**64%**	**64%**	**69%**	**72%**	**73%**	**76%**	**74%**
Regional IE	ETc Approach	**56%**	**59%**	**64%**	**70%**	**75%**	**78%**	**77%**

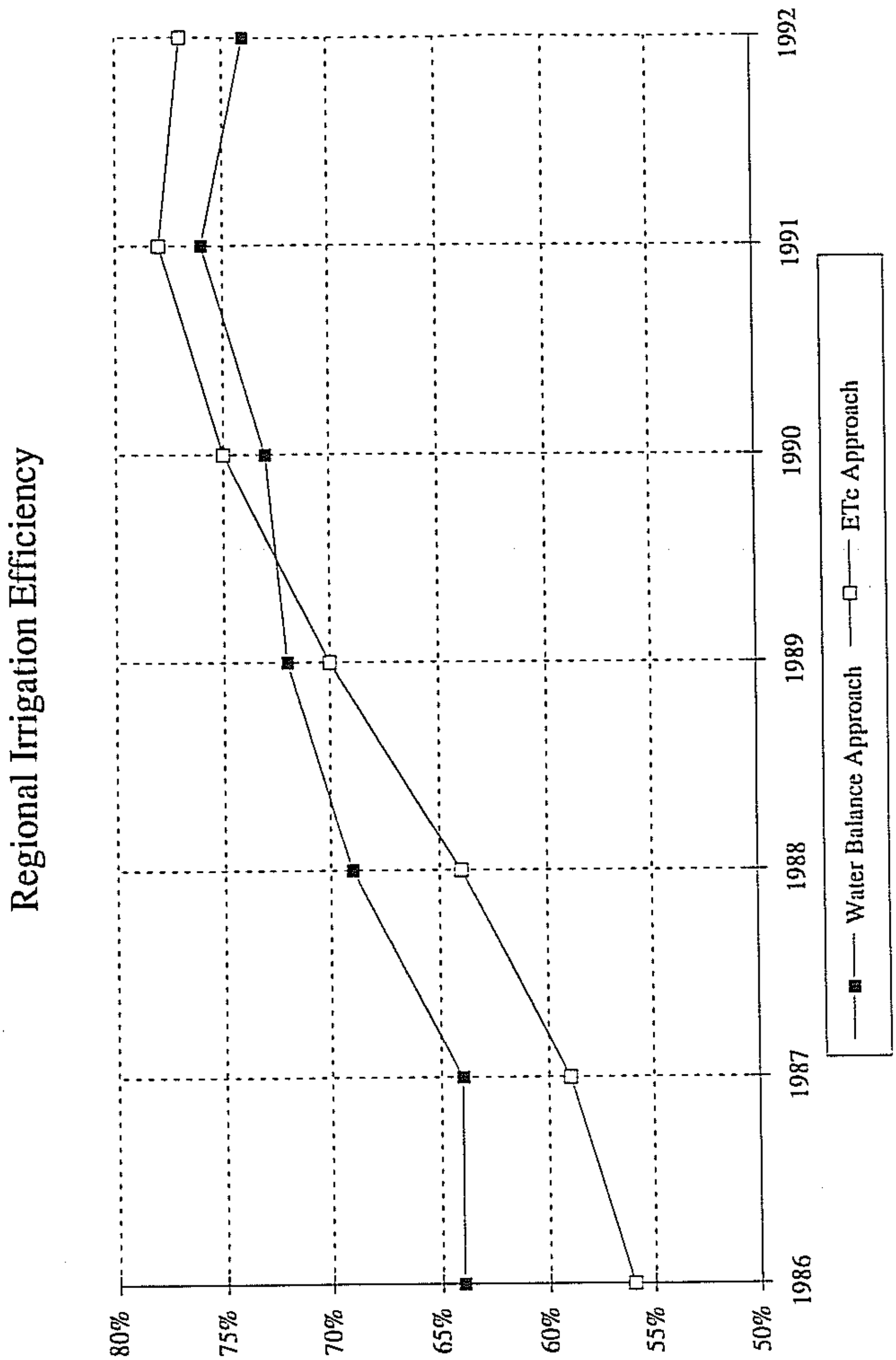

Regional Irrigation Efficiency
80%
75%
70%
65%
60%
55%
50%
1986
1987
1988
1989
1990
1991
1992
Water Balance Approach
ETc Approach

Figure 27

SECTION 6

RESULTS AND CONCLUSIONS

SUMMARY

There are several important concerns for the study area: the drought, increasing concerns over the quality of the San Joaquin River, and increasing pressure to reform federal water contracts and reclamation law. It would be impossible to say that the increasing trend is due to any one of these forces. Most likely it was an initial response to the water quality concerns brought out by the Kesterson Reservoir situation. Although pressure has remained to improve drainage quality, the overriding problem of the drought has become the main impetus for improved irrigation efficiency.

One effect of the drought may well be a reduction in the ETc adjustment factor as farmers stress crops. Another factor might be farmers planting more acreage than prudent; hoping for extra water to appear in mid-season. Without the additional water, some acreage will be abandoned. These abandoned acreages would have to be considered separately if performing further analyses in the same manner as this study.

The results of this study indicate that most of the districts were able to improve DIE. The main problem is whether they can maintain the high levels of irrigation efficiency without being impacted by increasing salinity in the rootzones. Based on the pre-plant analysis, the data indicated that significant underirrigation was being practiced due to the limited irrigation water supplies. If the trend were to continue, excessive levels of salts in the rootzone would be expected.

The results also indicate a basic need for better coordination among the districts in the data collection and recording efforts. The districts might invest in a common spreadsheet and word processing format to aid in information transfer. There has been much data collected for this study area. However, most of the data is not readily accessible for data analysis. Some of the data monitoring sites need to be improved. For example, wells and drainage sumps must be fitted with flowmeters. Other suggestions include standardized procedures for the collection of water quality data, improved drainage discharge point measuring stations, standardized format for reporting irrigated acreage and water delivery data (suggest the September through October format).

An important assumption made in this study was adjusting the ETc downwards to account for nonuniformity and bare spots. This tended to decrease DIE using the ETc approach because it decreases beneficial use for the same amount of applied irrigation water. But, even allowing that crop uniformity is variable throughout a field, and that bare spots do exist, there might be nothing a farmer could do about the perceived low DIE. That is, he cannot micro-manage irrigation within a field to prevent or reduce water application to poor or bare spots in any one field.

Other Significant Results:

- The water balance approach has identified several destinations of water that have not been used in previous reports. These include an estimate of the amount of rainfall runoff that enters the drains. The total amount ranged from about **4,500 AF to 10,000 AF** for the entire study area. Another estimated value was the amount of deep percolation losses below the Corcoran Clay layer. This report estimated losses of about **23,100 AF** per year for the study area. This is compared to the measured drainage volume in 1992 of **30,500 AF**. This is significant because a salt balance of this region needs to include an estimate of the salt removed with the water passing through the Corcoran Clay.

- Due to the fluctuating characteristics of the water quality data from the sumps and the district drains, it was felt it was not possible to draw conclusions regarding the expected selenium, salinity, or boron levels with additional recycling. Future data collection efforts need to focus on consistant water quality measurements and accurate flow measurement devices. Reported water quality measurements appear to use averaging techniques that may not accurately reflect the water quality in the drains. Some of the drainage discharge measurement sites need improvements to ensure accurate water measurement. Concentrations and loads analysis was graphically performed in **Appendix G**. Included in this section are EC, Se, B versus time of year, EC versus Drainage Volume, and EC versus Se ratios.

- In addition, special analysis were made of the sumps in Panoche Drainage District. It was found that 50% of the reported load of Se into the discharge of the district comes from 5 of 61 sumps. 80% of the loading comes from 10 of the sumps. These sumps are located close to each other on the eastern side of the district. If flows from these sumps could be minimized, the impact on the drain Se loading would be significant. Future studies may want to focus on water table control in these areas to minimize drainage volumes. For example, maintaining higher water tables could force additional upflux from the shallow water table. It is recognized that these regions may be draining significant flows from upslope water users. PDD has also been at the forefront in researching methods to remove harmful salts from the drainage water.

- It was found that the water quality from individual sumps varies significantly and that this is due to variations in the timing of the water quality samples. Apparently, water samples are drawn when convenient and cost concerns do not allow consideration for the timing of irrigation events. However, the data indicates that reductions in the drainage volumes will definitely reduce the EC, Se, and B loadings in the drains with the tradeoff of some increase in the concentrations.

There are two reasonable approaches available towards increasing the DIE in this area.

- The first is the classical approach of improved water management on both district and on-farm levels.

  - Improved on-farm irrigation efficiency implies improved timing of irrigations (in the sense of shutting off the water at the correct time) and better DU of water applications, plus recycling of tailwater on-farm. This improved on-farm irrigation reduces the two main on-farm water losses: deep percolation and uncollected tailwater.

  - Improved district level management involves recycling of reasonable quality tail and tile water, plus improved flexibility in water deliveries to the farms. Most of the districts have some capability of recycling tailwater. Firebaugh Canal Water District has just begun a study to evaluate the potential construction and blending requirements for recycling tailwater and higher quality tile water.

- The second path is a relatively new idea. This approach is an integrated approach which attempts to maximize the ratio of crop yield to the unit-water applied. Through improved management of the soil fertility, planting, irrigation, and other agronomic factors, the zones in a field which have weak or bare crop growth will be eliminated or minimized. Therefore, with a stronger crop, the field ET will increase because there are more and healthier plants. The applied water would remain about the same. The net result is less deep percolation and a higher IE.

Sustainable District Irrigation Efficiencies

There are two important and related questions which the ITRC has addressed in this study:

- What is the highest District Irrigation Efficiency (DIE) which can be sustained in this
- How much tile water recycling can be done?

The evidence to date indicates that the answers are three-fold:

- If there is under-irrigation on fields (caused by a combination of short durations and non-uniformity), any tile water recycling appears to be unsustainable in that some portions of the fields will accumulate unacceptably high and toxic salt levels.
- If there is no under-irrigation on fields (ie, all non-uniformity is compensated for with extra water application, and irrigation scheduling is sufficient to have no stress anywhere), about 30% of the deep percolation through the root zone can be recycled without raising the average root zone ECe to more than about 2.5 dS/m. The remaining 70% of the root zone deep percolation will either exit through the Corcoran Clay layer or be discharged (via tiles and then surface drains) from the district. Because of the uncertainties of the magnitude of the flow rate downward through the Corcoran Clay layer, it is impossible to predict the precise amount of tile water that must be discharged from the district via surface drains.
- The maximum sustainable DIE is about 80% in this region.

These conclusions are based upon the following:

1. All on-farm irrigation has non-uniformity (Distribution Uniformity, DU, of less than 100%) of water distribution across a field. Typical well-managed and well-designed irrigation systems have a DU of about 75-80%.

2. To avoid under-irrigation, with a DU of 75% and about 5% non-beneficial evaporation loss, the Irrigation Efficiency (IE) of a farm with no recycling is about 70%

$$IE = DU \times (1 - \frac{\%\ \text{evap loss}}{100})$$

$$= 75 \times (1 - \frac{5}{100})$$

$$= 71\%$$

3. A simple spread sheet was developed to examine soil salinities across a field with a linear DU pattern and varying percentages of tile recycling. A 30% recycling of root zone deep percolation, accomplished through blending tile water with supply water, indicated that the drainwater EC and blended water EC stabilize within a couple of years. This assumes **no under-irrigation** (a key assumption, as explained below). Estimated stabilized values were:

EC of source water = 0.6 dS/m (assumed)
ECe at "worst spot" in the field = 2.6 dS/m
ECe at "best spot" in the field = 0.5 dS/m

ECiw (blended) = 0.8 dS/m

ECdw = 2.5 dS/m

4. The numbers in item (3) above do not match what is actually seen in field. In particular, Broadview Water District has excellent data since about 1980. That data shows the following:

- Before BWD had an outlet for its tile drain water, the EC of the blended irrigation water was about 3.0 dS/m, higher than predicted in (3).

- This report has estimated that the present annual DIE values and pre-irrigation DIE values are in the range of 90%.

- Soil salinities measured throughout BWD by Lesch and Rhoades in 1991 are much higher than the ECe's predicted.

- The high DIE values in BWD are indicative of under-irrigation on parts of fields. That under-irrigation leads to salt build-up (due to no leaching) in some parts of fields, and very concentrated tile drain water in the areas with some leaching. That concentrated tile drain water is then recirculated on all the field, compounding the problem.

5. The district farmers see processing tomatoes as a key crop in their economic rotation. Tomatoes have a threshold (critical maximum) ECe of about 2.5 dS/m for soil salinity. Therefore, this discussion of sustainability revolves around the objective of maintaining a soil salinity distribution such that there is no yield decline of tomatoes anywhere in the field due to salt buildup.

In summary, the evidence indicates that the best strategy for soil productivity sustainability requires all three of the following:

- Have high irrigation DU's.
- Have excellent irrigation scheduling and water depth control, and avoid under-irrigation
- Recycle no more than about 30% of the root zone deep percolation, which may be equivalent to 40-60% of the tile water.

SECTION 7

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